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Art. X.—*Soil and Land Utilization Survey of the Country Around Berwick.*

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I. Introduction.

The object of the work reported here has been to obtain exact information concerning the potentialities and the present use of the land in a section of the coastal strip of south-eastern Australia in which rainfall is seldom seriously deficient. The provision of money from the University of Melbourne's Commonwealth Research Fund in 1937-38 made it possible to carry out a detailed study of a sample area in such country.

The area chosen for this survey covers 59 square miles and is centred approximately around Berwick, which is 27 miles east of Melbourne. Its boundaries do not coincide with those of a parish or shire, but were chosen in order to include representative portions of non-agricultural rugged hills, gentler foothills, and undulating to flat land. The general level of natural fertility in this area is low, though there are some fertile patches. The mean annual rainfall is 30 inches, increasing to 40 on the higher hills, and is fairly well distributed through the year. In all these respects the district is typical of Gippsland as a whole, although for statistical purposes it is included in the Central District, and lies just west of the boundary of Gippsland.

The survey consists of two main sections, namely, the mapping of soil types and the collection of information from the individual farmers as to their activities. For the latter purpose, questionnaire sheets were drawn up to deal with each of the main occupations. Circulars were first sent to all farmers with a holding of more than 20 acres, explaining the object and nature of the inquiry. Each of these farmers was later visited and the soils on his property were mapped. The information has been so tabulated that no details of any individual farmer's activities are disclosed.

The project was greatly facilitated through the kindness of the Royal Australian Air Force in providing us with aerial photographs at the scale of 4 inches to the mile. The individual contact prints, measuring 7 inches square and covering 1,980 acres, proved invaluable in the field in providing reference points for mapping and in indicating boundaries of properties and of soil types; these prints were also very helpful in arousing the interest of many of the farmers. We should like to record here our gratitude to the Royal Australian Air Force.

II. Description of the Surveyed Area.

The location of the area is shown in fig. 1, together with the railways and chief towns in the neighbourhood. Dandenong, with over 4,000 inhabitants, is the largest town in the neighbourhood and is one of the most important markets for livestock in the State. It is the terminus of a suburban electric-train service from Melbourne. The surveyed area was chosen with the idea that it was far enough away from the metropolis to be free from any suburban characters; though this is not quite correct, it is approximately true. The area is typically rural; the only factory in the district is one at Officer, at which building tiles and pipes for agricultural drains are made.

Topography.

The surveyed area may be divided into two portions, lying north and south of the main road from Melbourne to Sale (the Princes Highway). This coincides roughly with the 200-foot contour (as shown on the Military Survey).

The land to the north of the highway is hilly, and constitutes the south-western extremity of the great mountain chain of eastern Victoria; the highest point within our area is Upper Beaconsfield (700 feet), and the 1,000-ft. contour lies 5 miles away to the north. The hills to the east of Cardinia Creek are fairly steep, slopes of 14 degrees being frequent. West of Cardinia Creek the round-topped hills of basalt are the dominant feature. Slopes are generally gentler here, and the highest point, west of Harkaway, is 550 feet, from which the country falls away sharply to the west.

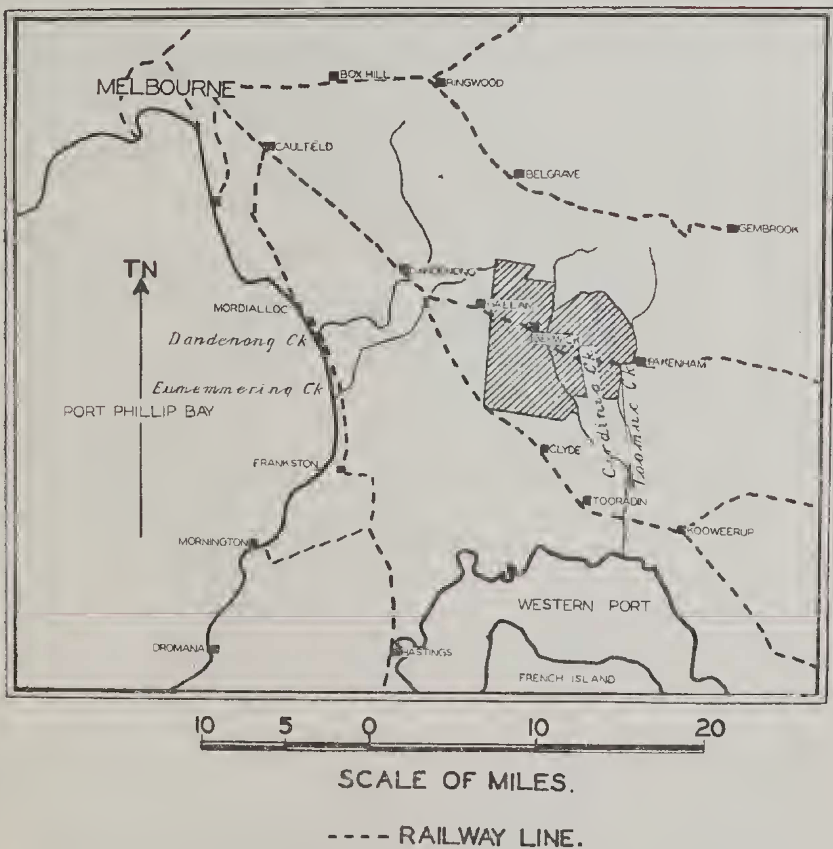


FIG. 1.—Position of surveyed area relative to surrounding country.

The land to the south of the highway is gently undulating or flat, except for a few hills near Berwick, and the 200-ft. contour comes south of the road at only a few points. The 50-ft. contour includes the south-eastern corner of the area, and from here to the coast of Westernport Bay (9 miles away) the land is very flat. This country to the south-east of our area is the great basin of Koo-wee-rup, formerly a swamp and now reclaimed by means of a network of drains and embankments.

NATURAL DRAINAGE.

Cardinia Creek and Toomuc Creek, which rise about 5 miles away to the north, are the only well-defined streams. Little water runs in them in summer and autumn, but their flow does not cease altogether except in the severest drought. Further to the south the two creeks join and the water flows through one of the major drains of the Koo-wee-rup scheme into Westernport Bay.

The western part of the area drains by the Eumemmering Creek into Port Phillip Bay. Hallam Valley, lying just south of Berwick and Narre Warren, collects water which joins the Eumemmering 4 miles to the west of Narre Warren. The divide between these two systems is defined by the ridge of basalt coming through Harkaway and Berwick to the south of Beaconsfield, and then swinging south-west to Cranbourne.

There are numerous minor watercourses, most of which are artificial and have been cut in order to drain swampy patches. Many of these have scoured, even in very gently sloping country. Toomuc Creek itself provides a striking example. This creek formerly spread over flat country near its present course with no defined bed, and the present narrow course from the point where the main road crosses it has been scoured out since the land was settled, having been started, according to tradition, by a furrow that was scooped out for the purpose of drainage. Even more spectacular ravines have been scoured out at the foot of the hills north from Narre Warren (see pl. X, fig. 3). In one property a straight drain was cut in the early days of settlement and a gully has now been formed 30 feet deep and over half a mile long, bisecting the farmer's property. The rapid run-off of water from the deforested hills around has probably contributed to this effect.

Geology.

Kitson's rapid survey (1) in 1901 of the country around Berwick is the only account of the geology of this district, except for a note (2) on the unimportant gold mining in Haunted Gully, where the reservoir now lies for the supply of water to Mornington Peninsula. The geological boundaries as defined in the present survey are shown in fig. 2.

The geological history of the district is as follows. The bedrock consists of folded and compressed Silurian marine mudstones which are soft where they are exposed. In the Devonian age there was an intrusion of granodiorite below the surface of the Silurian bedrock. This granodiorite has since been exposed in places in the north (such as Harkaway) by the erosion of the Silurian rocks. In Oligocene or Lower Miocene times streams of basaltic lava started near the northern fringe of the area and flowed through the valleys, moving first south and then southwest through Cranbourne. The present surface of this flow is 600 feet above sea-level just north of Harkaway, 300 feet at Berwick township, and 100 feet at Cranbourne, after which it is lost below the present level of the land. There were at least two flows of this basalt, the later flow being denser (3); they are

FIG. 2.—Geological Map of Berwick Area.

separated or covered by a sandy sediment in a few places giving rise to some curious mixed soil profiles in which the upper and lower layers are developed from different materials. There is a good example at the northern end of Wilson's quarry at Berwick. Here a foot of light-grey sandy loam which could not have been formed from basalt overlies the material derived from the lower flow of basalt.

The Silurian rocks have been eroded more rapidly than the basalt, with the result that the basalt which once filled the valley now stands out as smooth hills with rather steep sides. At some places, such as the town of Berwick itself, the process has reached the stage where the Silurian rock and the basalt are on about the same level. Near Harkaway the basalt rests on granodiorite, and here also is a ridge with both rocks on the same level.

The flat and undulating country to the south of the highway is formed of material brought down from the granodiorite and from the Silurian rocks. Frequent changes in course and in the fineness of the material carried by former creeks have resulted in the high variability of the soil to-day over much of this southern country. A few gentle hills of Silurian rock remain uncovered, dotted here and there over the plain. The land has been mapped as "colluvium" wherever there is no rock within 6 feet of the surface.

Definite remnants of Tertiary river-beds occur at a few places; there are two groups of these, a deep sand and a gravelly clay. Both of these deposits are quarried for local use. The so-called gravel beds are used for road-making, but are undesirably high in clay for the purpose. We have not attempted to map the boundaries of these gravelly deposits accurately, but have merely marked the sites of gravel pits. It is possible that some of the land marked on the soil map as "Toomuc sandy loam" is derived from the same Tertiary deposits.

III. Climate.

Total Annual Rainfall.

The mean annual rainfall over the country south of the highway is close to 30 inches. There are no stations within this area which send in daily reports to the weather bureau at Melbourne, but monthly records have been kept since 1887 by the Patterson family, now at "Jesmond Dene," Cardinia Creek (4). The average here to the end of 1937 is 31.55 inches. We have also used the figures which have been either taken from (4) or supplied from personal records by the courtesy of local residents, for several other places, including Narre Warren, Berwick, Pakenham, Cranbourne, and Clyde. Some of these records extend over too short a period to calculate a reliable average, but if the figures are compared with those for the same years at "Jesmond Dene," and it is assumed that the mean ratio of the rainfall of each station to that of "Jesmond Dene" remains steady, it appears that all these stations have between 28.5 and 30.5 inches. A rainfall of about 30 inches is the rule in the flatter country within 25 miles east of Port Phillip Bay, and the excess of rain over that falling at Melbourne (average 25.6 inches) is probably due to the moisture carried by westerly and south-westerly winds which have recently passed over water.

The annual rainfall at "Jesmond Dene" has ranged from 46.54 inches in 1924 to 18.39 inches in 1908. The median rainfall is 31.25 inches. The mean deviation of all years from this median is 4.45 inches or 14 per cent.

North of the highway, rainfall increases sharply with altitude. Upper Beaconsfield, 700 feet high, with 38.5 inches, is typical of the higher land within the surveyed area, and the orchards in the foothills above Officer probably receive about 33 inches.

Distribution and Effectiveness of the Rain.

The value of a given annual rainfall naturally depends on its monthly distribution. The monthly averages for "Jesmond Dene" are given in Table I. Temperature and evaporation are not recorded in this district, but the mean figures for Melbourne must be close to the local values and they are therefore incorporated in the table.

Table I.—Mean Monthly Rainfall from 1887 to 1937 at "Jesmond Dene," Cardinia Creek, and Mean Figures for Temperature and Evaporation at Melbourne.

—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Rain ..	214	159	257	288	270	277	271	279	298	328	249	265	3,155
Temp. ..	67·4	67·6	64·6	59·4	54·1	50·4	48·8	51·0	54·1	57·7	61·3	64·9	58·4
Evap. ..	643	504	401	241	149	113	109	150	232	336	454	574	3,905

Rain and evaporation are recorded in "points" of one hundredth of an inch.

Although at first sight it appears that the rainfall is evenly distributed, the year is in fact divided into a wet season (winter and early spring) and a dry season (summer and early autumn). The climate has some of the character of the Mediterranean type of dry summer and wet winter, but differs from it in the extension of the rainy season well into the spring and in the occurrence of erratic storms of tropical origin which particularly favour the eastern half of Victoria during the summer and early autumn. Apart from these irregular tropical spells, the summer is typically dry and sunny, with occasional bouts of hot north winds blowing from the arid interior, which contribute to the high evaporation. The liability to dry spells may best be seen from Table II, in which the median rainfall is tabulated instead of the mean. Since

TABLE II.—VABIABILITY OF MONTHLY RAINFALL AT "JESMOND DENE," 1887-1937.

—	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Median rainfall ..	168	104	215	263	255	273	261	270	272	323	222	250
Mean deviation from median ..	125	105	135	146	95	96	90	88	92	124	109	122
Percentage deviation	74	101	63	55	37	35	34	33	34	38	49	49
No. of times month's rain fell below 1 inch ..	14	22	12	6	3	3	3	0	1	3	7	9

the chances are equal that in any year or month the rain will be below the median, it is a more informative figure than the arithmetical mean, which may be compounded from several dry months and a few very wet ones. This table demonstrates the high reliability of the rain during the six cooler months, May to October, whether one considers the percentage variability or the possibility of a total of less than 1 inch. Fig. 3 illustrates the most important material in Tables I and II. The high reliability of rain in spring is especially important, since the temperature is then high enough for rapid growth. In fact, from 1885 to 1937 the combined rainfall in September and October had only three times fallen below $3\frac{1}{2}$ inches, viz., in 1888, 1896, and 1914. In 1938 the figure was only 173 points, and since the autumn of 1938 was also abnormally hot and dry, this year stands out as the worst since records were taken.

Summer rainfall is arratic and is generally too low to be of much use to plants except in abnormally wet years, in which the growth of pastures is prolonged well into the summer. If we use Trumble's principle (5) that the moisture in the soil falls below the point at which plants permanently wilt when the ratio of rainfall to evaporation (P/E) is less than one-third, then in 29 summers out of 50 there were at least two successive months too dry for growth. Or taking the arbitrary standard that a month with P/E less than one-half is dry, there were 30 summers with at least three such dry months in succession. In spite of this, summer-growing forage crops—especially maize and millet—are widely used. These are sown in late spring, when rainfall is relatively reliable, and they grow on the moisture conserved in the wetter months. The more clayey soils of the depressions naturally hold greater reserves of water, so that they can be used relatively safely for summer crops without gambling on the weather. Possibly the maize plants on some of the depressions get their roots within reach of permanent water.

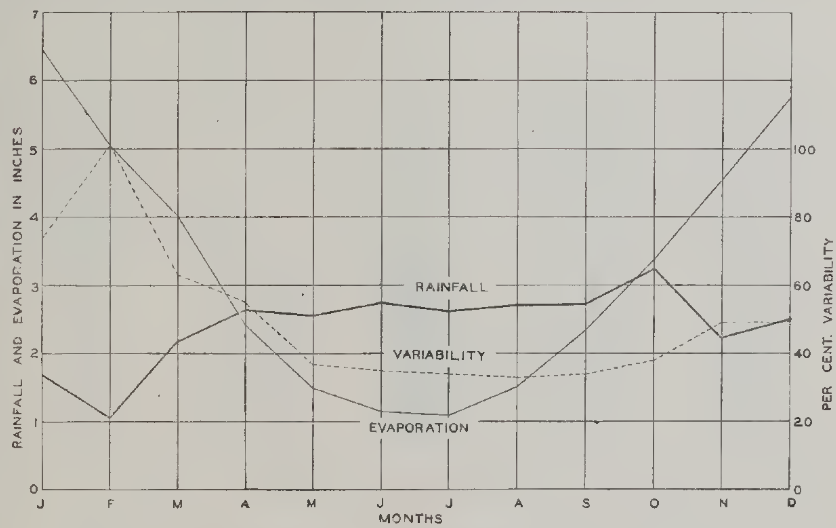


FIG. 3.—Median monthly rainfall, showing also percentage variability and mean evaporation.

Pastures are however far more important here than crops, and the most valuable constituents of the pastures are subterranean clover and perennial rye grass. With regard to these, the most important among the more variable factors in the weather is the "break of the season" in autumn—that is, the date after which the soil does not dry out until the following summer. This "break" may occur at any time from early March to mid May, and the earlier date is highly desirable, since rain coming while the soil is warm allows the annual plants to become well established.

Much the same general considerations apply to the settled hilly country for about 2 miles to the north of the highway as to the flatter country to the south. These foothills receive 10 to 20 per cent. more rain, and presumably lose less water by evaporation. The natural rainfall, however, is often too little for the orchards during the summer, and many orchardists irrigate their trees.

During June, July, and August frosts are not severe, and in the majority of winters the air temperature never falls below freezing-point. However, the mean temperature of the soil, again using the Melbourne records, is between 45° and 50°F., and this is too low for rapid growth. During winter and early spring there is no lack of rain; on the contrary, there is often an excess, and the saturation of the soil helps to keep growth at a low rate. The subsoils consist generally of relatively impermeable clay, and it is likely that drainage is a limiting factor to growth throughout the district. The effect of the cold period in winter is well shown in the very low figures for the growth of pastures for almost all stations in Southern Victoria which have been recorded by the Victorian Pasture Improvement League and published from time to time in the Journal of the Department of Agriculture of Victoria. The local conception of a "good winter" is one with rain below the average, and therefore with a minimum of water-logging.

IV. Description of Soil Types.

The basis of the classification and mapping of the soils (see fig. 6) is the *profile*—that is, the set of characteristics which one observes in the face of a pit, or occasionally in a roadside cutting. Such a profile consists of a succession of layers, known as horizons, differing from one another in texture and colour, and other less obvious features. Each "soil type" is known by a place-name and a term which describes the texture of the surface soil. The same place-name may be attached to two types if they are closely related to each other.

The soil types described in this section fall into four main groups, namely:—

Podzolic types,

Heavier soils on low-lying land,

Soils developed on basalt,

Miscellaneous, unnamed types.

Podzolic Types.

The predominant tendency among soils both in the surveyed area and in Gippsland is to develop a profile with the characteristics of a "podzol." A "podzol" develops typically in regions of fairly heavy winter rainfall; it has a low reserve of calcium, magnesium, and potassium, which have been washed away with drainage water, and consequently it is definitely acidic. Its reserve of phosphate is similarly low. Physically, much of the finest material has been removed from the upper layers and concentrated at lower depths, so that the sandy surface contrasts sharply with a clayey subsoil. Further, the downward movement of iron compounds has left the surface grey, and has given the subsoil a yellow shade. Some podzols are also marked by a particularly light colour just below the surface (see pl. X). The colour and texture of the five podzolic types of this district are illustrated in fig. 4.

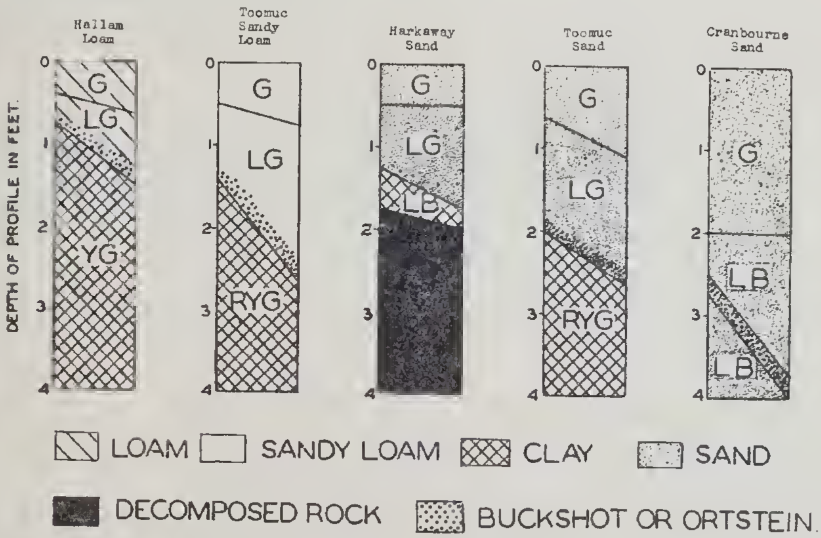


FIG. 4.—Profiles of five Podzolic soil types. Letters stand for colours as follows:—B, brown; G, grey; L, light; R, red; Y, yellow.

1. *Harkaway Sand.* (See also pl. X, fig. 2.)

This type is found on the granodiorite in the hilly country to the north. Boulders several feet across occupy some of the land, but in many places the soil is deep; this combination of boulders with deep soil is commonly found in country developed from granite or granodiorite. The typical profile is as follows:—

Horizon 1. (0–6 inches)—Grey loamy sand or sandy loam.

Horizon 2. (6–18 inches)—Light-grey sand. Soft concretions containing iron oxide and organic matter may occur near the bottom of this sandy horizon.

Horizon 3. (18–24 inches)—Sandy clay, often with a greasy feel due to mica. The colour is a mottling of grey, yellow, and red, with red predominating.

Horizon 4. (24 inches downwards)—This sandy clay grades imperceptibly into decomposing rock, in which the amount of clay gradually diminishes with depth as a smaller proportion of clay-forming minerals are decomposed.

The transition from Horizon 2 to 3 is very sharp, and may take place at any depth from 15 to 21 inches. This marked difference between surface and subsoil is usually a sign that the soil is highly mature—implying, in this case, that the rain has already washed away the reserves of valuable elements.

However, the persistence of small grains of hornblende and other primary minerals in the surface layers, as revealed by microscopic examination of the "fine sand" fraction, is a redeeming feature of these soils, and the analysis of a single sample indicates that this type is better provided with potassium than the other light types of the district.

2. *Cranbourne Sand.*

This is found especially in the south-west of the area. It has been developed on deep sand deposited by rivers in Tertiary times, the original source of the quartz sand being the granodiorite from the hills to the north. It is likely that this sand has been affected by wind-blowing since it was laid down. The typical profile is as follows:—

Horizon 1. (0–23 inches)—Grey loose sand, becoming lighter in colour below about 9 inches.

Horizon 2. (23–46 inches)—Light-brown sand.

Horizon 3. (46–48 inches)—Dark-brown cemented layer. This consists of sand cemented together by organic matter and other material washed down in colloidal solution. It is described in other countries by the German term "Ortstein", and is locally known as "coffee-rock".

Horizon 4. (48–78 inches)—Sand containing small nodules of clay. Though the percentage of clay is very low, its presence is obvious to the feel. This layer is often wet. In many places the sand extends to a depth of many feet.

The vegetation of this type (see p. 236) is characteristic. It has been left uncleared longer than any other type on the south of the main road, since it is chemically very poor, and is so sandy that it retains very little water as a reserve against drought.

3. *Toomuc Sand.*

This soil has developed on mixed colluvial material derived from granodiorite and Silurian mudstone. It occurs mainly as small ridges 1 foot or more above the level of Toomuc sandy loam, a more important type with which it is usually associated.

The following is a typical profile:—

Horizon 1. (0–10 inches)—Grey loose sand, becoming lighter in colour with depth.

Horizon 2. (10–31 inches)—Light-grey sand, sometimes with a brownish colour.

Horizon 3. (31–33 inches)—Ironstone gravel or continuous ortstein ("coffee rock") rests on the top of the clay.

Horizon 4. (33 inches downwards)—Sandy clay, grey with red and yellow mottling, persisting to a depth of several feet.

Rushes grow on many patches of this type, giving evidence that underdrainage is particularly poor.

4. *Toomuc Sandy Loam.*

This has also developed on the material washed down from the hills, or in some cases from Tertiary sediments that have been consolidated to form ridges of sandy or gravelly clay. The typical profile is as follows:—

Horizon 1. (0–6 inches)—Grey or light-grey sandy loam.

Horizon 2. (6–24 inches)—Very light-grey sandy loam or sand. Concretions of ironstone gravel are common at the bottom of this layer. In wet weather this layer becomes a semi-fluid mass and animals or machinery may sink deep into it. This is an example of the popularly termed "spewy" soil.

Horizon 3. (24–46 inches)—Light to medium clay, mottled yellow and grey, with red mottling increasing with depth.

Horizon 4. (46 inches downwards)—Light red-brown heavy clay.

The transition between horizons 2 and 3 is sharp. The depth at which clay occurs is normally between 20 and 26 inches, but it may be as little as 17 inches. Every transitional stage between this type and the next one (Hallam loam) occurs in the field. It shares with Hallam loam the unpleasant property of readily forming very hard clods.

5. *Hallam Loam.*

This type is formed on the material washed from the hills on to the lower, gentle slopes. Most of this material is derived from Silurian hills. The following is a typical profile:—

Horizon 1. (0–6 inches)—Grey or light-grey loam, with a floury feel due to its high content of silt. Liable to set very hard after rain.

Horizon 2. (6–13 inches)—Light-grey loam, or silty loam. This is quite structureless and is like the sub-surface of Toomuc sandy loam. Charcoal is very common in this horizon.

Horizon 3. (13–16 inches)—Light brownish-grey clay loam. Concretions of ironstone are characteristically but not invariably present. The presence of concretions at this level is doubtless due to the frequently semi-fluid nature of the surface layers through which the ironstone sinks, till it rests above the clay.

Horizon 4. (16–30 inches)—Greyish-brown heavy clay, only slowly permeable to water.

Horizon 5. (30 inches downwards)—Heavy clay with red, yellow and grey mottling.

The clay may continue for many feet, merging gradually into decomposed Silurian rock. As with the Toomuc types, the contrast between the grey loam at the surface and the yellowish clay of the subsoil is very marked, and the transitional layer (Horizon 3) is often absent. The frequent ironstone gravel, which is up to half an inch in diameter, bears witness to the fact that drainage has periodically been very slow and the subsurface waterlogged. The depth of the impermeable clay layer is usually 12-16 inches, but may be found anywhere between 9 and 20 inches.

5. (*a*) *Hallam Loam* (*Silurian Phase*). (See pl. X, fig. 1.)

There is little essential difference between the soils formed directly on the Silurian rock and those formed on the wash from the hills. In all cases there is a high percentage of silt throughout the profile, and a transition at a depth of about 1 foot from a grey silty loam to a yellowish-grey impermeable clay. Where the rock occurs within 6 feet of the surface we have mapped the soil as the "Silurian Phase." Most of the country so mapped has rock within 3 or 4 feet of the surface. This naturally occurs on the top and the upper slopes of hills. The layer of gravel lying above the subsoil clay consists partly of smooth ironstone grains, many of which are nearly spherical, and partly of long yellowish flakes of siliceous material, presumably fragments of parent rock, cemented by iron compounds and so made resistant to weathering.

The weathered Silurian rock has a remarkably yellow colour, and this shade is characteristic also of the subsoils of this phase.

5. (*b*) *Rugged Silurian Country.*

The surface of Hallam loam is easily converted by rain into an amorphous semi-fluid mass, which is particularly liable to sheet erosion. Consequently, the depth of surface soil is much less on the steeper slopes, and only shallow, rocky soils occur in the northern country where slopes of about 14 degrees are common. Such soils are non-agricultural, and have been mapped as a separate type.

HEAVIER SOILS ON LOW-LYING LAND. (See fig. 5.)

The two types that come under this heading contain more clay than those just described, and consequently do not show any marked contrast of light surface and heavy subsoil. They occur on low-lying land, and it is clear that they have been continually receiving fine material that has been washed down from the higher land around them. Thus they not only differ from the podzolic soils in the absence of contrast between the surface and subsoil and by their waterlogging for long periods, but the method of their formation also gives them a quality of relative immaturity. The natural vegetation is swamp tea-tree, and several strips of this still remain.

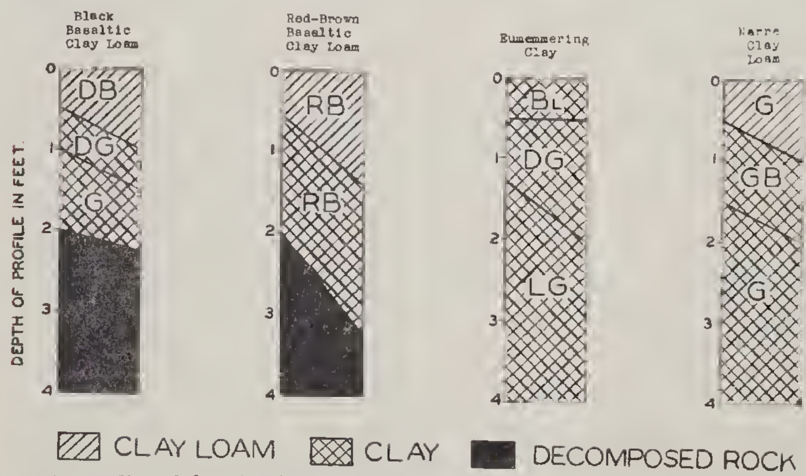


FIG. 5.—Profiles of four heavier soil types showing the colour and range in depth of the various horizons. Letters stand for colours as follows:—B, brown; BL, black; G, grey; D, dark; L, light; R, red.

6. *Narre Clay Loam.*

This occurs in depressions, often as long tongues corresponding to drainage lines, among the lighter types in the country to the south.

The following profile is typical:—

Horizon 1. (0–9 inches)—Grey clay loam with brown mottling.

Horizon 2. (9–18 inches)—Grey light clay with brown mottling.

Horizon 3. (18–31 inches)—Grey clay.

Horizon 4. (31 inches downwards)—Clay, mottled with grey, yellow and red, extending for several feet.

It is characteristic that light clay occurs at a depth less than 12 inches. The brown mottling of the surface soil is characteristic, and indicates the conditions of poor drainage under which the soil has been developed; the alternate reduction of iron compounds during periods of waterlogging and their oxidation during dry spells has led here to the deposition of ferric oxide as rusty streaks rather than as gravelly concretions. The soil cracks in dry weather and is often difficult to work, but it is regarded in the district as a desirable type. The clay in the deep subsoil is sometimes relatively light, especially where the type occurs on the higher levels. This is due to the fact that this soil is formed on natural lines of drainage, down which sand has been washed as well as the finer fractions. Some of the tongues of this type in the south-east of our area have important amounts of coarse sand, and approximate in texture to a sandy clay loam.

7. *Eumemmering Clay.*

The main continuous occurrence of this type is one of 1,010 acres in the Hallam Valley section, on land draining into the Eumemmering Creek. It also occurs in other basins where minor watercourses have spread over the land in such situations that the movement of water has been slow enough to allow suspended clay to settle, while swampy conditions have persisted long enough each year to allow a fair accumulation of organic matter. The swamp tea-tree reaches its greatest development in this environment.

The following profile is typical:—

Horizon 1. (0–6 inches)—Black clay, somewhat friable, drying into small crumbs when properly worked.

Horizon 2. (6–16 inches)—Dark-grey plastic, heavy clay.

Horizon 3. (16–35 inches)—Grey plastic, heavy clay.

Horizon 4. (35 inches downwards)—Heavy clay, with light-grey and yellow mottling.

The depth of the friable surface layer may be as little as 3 inches. It is at the best a refractory soil which can be easily worked only over a narrow range of moisture contents. It is particularly troublesome during the frequent wet winters and springs.

This soil invites comparison with the types found in the Koo-wee-rup district, which also was formerly a tea-tree swamp. No detailed survey has been done in this district, but the better soils have a great reputation and have produced splendid crops of potatoes. This first-class land of Koo-wee-rup, however, at such places as Dalmore is relatively peaty, and it is said that it can be worked at any moisture content. Eumemmering clay is not at all peaty, and is probably comparable to the second-class land of the outer areas of the former swamp of Koo-wee-rup. Such land was probably wet for only certain periods of the year and did not therefore accumulate as much organic matter as did the more permanently swampy land. Eumemmering clay to-day contains only about half as much organic matter as the better Koo-wee-rup types, and its subsoil is far less permeable. The quality of Eumemmering clay does not seem to be associated with the nature of the hills from which the clay has been brought down. Thus Hallam Valley, receiving its material from hills of basalt and Silurian rock, appears closely similar to other basins of Eumemmering clay deriving their material from Silurian hills only.

Soils Developed on Basalt. (See fig. 5.)

The soils developed on the basalt are strikingly different from the others in the district. The horizons grade imperceptibly into one another and there has been no visibly recognizable removal of iron compounds from the surface. Two types have been mapped, according to the colour of the surface soil. They are of small extent and have not been given names beyond the description of colour.

8. *Red-brown Clay Loam on Basalt.*

This type is usually spoken of as "red"; the following is a typical profile:—

Horizon 1. (0–9 inches)—Dark red-brown clay loam, rich in organic matter and very friable.

Horizon 2. (9–17 inches)—Reddish-brown friable clay loam, differing from surface soil mainly by its lower content of organic matter.

Horizon 3. (17–27 inches)—Red friable clay.

Horizon 4. (27–39 inches)—Red friable clay mottled with yellow.

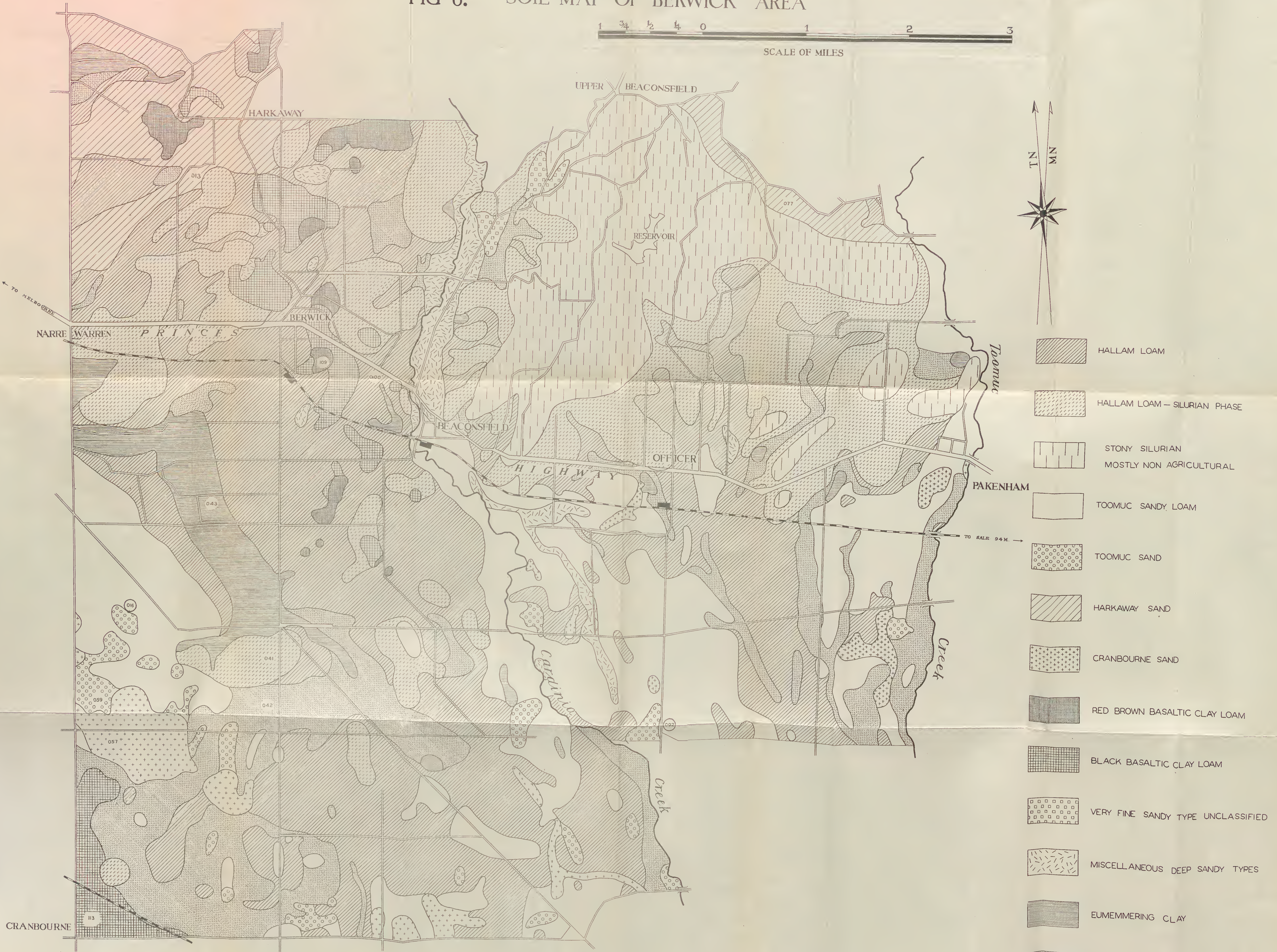
Horizon 5. (39 inches downwards)—Light-brown decomposing basalt, of the texture of a gritty loam.

Many red soils are shallower and more stony than this type sample (C 109). Near the edge of flows a variety occurs containing large concretions of ironstone. This covers a small area, and is not mapped.

9. *Black Clay Loam on Basalt.*

Horizon 1. (0–10 inches)—Very dark-brown to black clay loam, rich in organic matter and fairly friable.

FIG 6. SOIL MAP OF BERWICK AREA



Horizon 2. (10–27 inches)—Grey or dark-grey heavy clay.

Horizon 3. (27 inches downwards)—Decomposing basalt, light-brown and gritty.

Strictly speaking one should distinguish between the black soils on higher slopes and those on the gentler, lower slopes. It is quite plain that the latter crack more on drying than the former, and as might be expected they have a deeper subsoil, in which the clay is as plastic and heavy as any in the district. The type sample was chosen as it occurs in the only extensive patch of black soil on basalt, but is not thoroughly representative, because being low-lying it has received both quartz sand and finer material from surrounding non-basaltic land. All these basaltic soils appear to be resistant to erosion, are rich in organic matter and friable considering their clay content, and possess a stable crumb structure which confers on them a good permeability. Small rocks or "floaters" occur through the profile, and often make it impossible to sample below a few inches. Every intermediate colour occurs between the extremes of "red" and "black"; only the soils with really bright colours are mapped here as "red", the rest being "black".

The reason for the existence of the two types is not known. Similar contrasts occur farther east in Gippsland, and it seems very likely that these soils are analogous to the basaltic soils around Burnie, in North-western Tasmania, which have been surveyed by Stephens (6). Differences in soil type are not associated with any difference in the parent rock or in topography, except that red soils are not found on flat land. It is said that the black soils hold the moisture better and give heavier crops, but the red are more easily worked.

The native flora was undoubtedly very dense, and has left its mark in the high organic matter of the soil. To-day an occasional tall "white gum" (*E. viminalis*) remains on the basaltic country, a tree that contrasts with the much smaller "peppermints" around it on the podzolized types.

A very interesting feature of the basaltic ridges is the suddenness with which the soil changes at the foot of the slope into the poor podzolic type; the effect of basaltic wash is evidently very slight.

Miscellaneous Types.

A few areas have been mapped as "miscellaneous sandy types." These are all podzolic and naturally poor.

(i) Along Cardinia Creek is a line of deep sand, which is presumably a former bed of the creek. The profile varies from place to place, but typically there is sand to a depth of 4 to 5 feet, overlying a yellowish sandy clay. The sand is generally less coarse than Cranbourne sand; its colour ranges from grey at the surface to light-brown in the lower levels, which sometimes contain soft brown concretions. Several small pits have been worked for this sand.

(ii) A small patch of deep fine sand changing to clayey sand below 4 feet occurs north-east of Officer. Its geological origin is obscure.

(iii) Interbasaltic sands.—Sandy deposits occur on the edge of the lava flows to the north of Berwick. Three of these consist of coarse sand, and the soil developed on them is grey coarse sand turning to light-grey below the surface, and changing at 3 feet to reddish-brown coarse sand with small inclusions of clay. A fourth deposit, covering a larger area than any of the others, consists of finer material, though probably it also was deposited by streams flowing at the edge of the basalt. The soil developed on this is a grey fine sand with ironstone concretions at 18 inches, lying over mottled red and yellow clay at 22 inches.

(iv) An unclassified "very fine sandy type" has been mapped with a different symbol from the soils just described. This soil occurs north of Beaconsfield, and has a remarkably silty feel, due to the large proportion of very fine sand which it contains. The surface is a grey silty loam, and the colour becomes lighter with depth: this passes at 22 inches into a yellowish-grey silty clay, and at 33 inches into a light clay which is mottled with red, yellow, and grey. This soil appears to be developed from foot-hill wash from the Silurian hills, which seem to have provided at this point an abnormal concentration of very fine sand and silt.

Significance of Soil Type.

The foregoing descriptions, and the more detailed analyses in a later section of the paper, show how greatly the soils of this district differ from one another. If the production of cash crops were common here, no doubt these differences would be reflected in the agricultural reputations of the various types. All the land is capable of being cropped, except where the slopes are too steep. However, grass is by far the most important crop throughout the district, except the Silurian hills where fruit is grown. It appears that, with the exception of the non-agricultural Silurian hills, there is little to choose between the various soil types as regards the productivity of well-managed pastures. Good pastures, including perennial rye grass, can certainly be established on all these types. However, the general development of good pastures in this district is so recent that there is no guarantee that the perennial pastures on the soils of low inherent ferility will prove as permanent as those on the better soils.

It is not possible to compare the various soil types with one another on the score of prices paid when land changes hands, but the soils on the basalt would probably command a higher price than the others.

Saline Patches.

Patches of land affected by a high concentration of salt are a conspicuous feature of the country, especially within 2 or 3 miles from Narre Warren. These patches occur at the foot of gentle slopes, and may spread out for 150 yards or more over the flats. The only plant that grows on most of them is a stunted form of a species of Plantago, and as shown in plate XI this alternates with bare ground. The immediately surrounding land carries less tolerant plants (see p. 237), and a few yards further away there may be normal pasture.

These concentrations of salt are evidently associated with certain properties of climate, topography, and soil. It is at first sight surprising to find accumulations of salt under an annual rainfall of 30 inches, with low evaporation during the winter. However, most of the rain comes as relatively light showers, and falls of over 1 inch in 24 hours make only a minor contribution to the yearly total; on this account, salt is not washed out so thoroughly as in districts where each fall of rain is heavy. The salt falls with the rain, being blown in from the sea in the form of evaporated spray, and its occurrence is not connected with the weathering of rocks. This matter has been fully discussed by Prescott (7) for Australia in general, and by Teakle (8) for the south-west of Western Australia. It may be estimated from unpublished data kindly supplied by Mr. V. G. Anderson that the annual fall of sodium chloride on the land near Berwick is 80 pounds per acre. The local concentration of this salt to give 10 tons per acre in the surface foot depends on soil and topography.

The soil of the ridges above the salt patches is one of the podzolic types, Hallam loam or Toomuc sandy loam, with a sharp boundary between the permeable surface and the subsoil, which is only slowly permeable. The rain after saturating the surface layers flows down the hill on the top of the clay, becoming more saline on its way as pure water is evaporated or transpired by plants. The water when it is checked at the foot of a slope may thus contain the salt that has fallen over many times the area of the salt patch.

History.

These salt patches are characteristically much more acidic than the surrounding land. This fact suggests that the high concentrations of salt are recent, since land that has long been influenced by salt is usually neutral or alkaline. The older settlers also believe that the salt has appeared or has spread since the land was cleared, as has undoubtedly been the case elsewhere in Australia. However, it is said that there were at least a few salt patches when the land was first settled.

Treatment.

These patches make up so small a proportion of the average holding that even the most progressive farmers have not taken measures against them. The barrenness is certainly due to salt and not to acidity; liming does not improve matters. Crops which tolerate high concentrations of salt have not been tried.

V. Land Utilization: (A) General Considerations.

HISTORICAL INTRODUCTION.

When Victoria was first occupied by white men the whole of this district was covered by forests of various species of Eucalyptus, or by dense scrub on some of the flats. Settlers first arrived about 1835, but their numbers were small until the completion of the first survey by the Lands Office in 1852. In this survey the virgin bush was divided into blocks mostly of 640 acres, with a few of 320 acres; roads were marked out and small areas set aside for townships.

When the survey was completed the Lands Office offered some of the blocks for sale to members of the general public for £1 an acre. However, many of the eventual settlers had to pay considerably more than this, partly because some of the land was auctioned by the State but mainly as a result of the activity of speculators. Many blocks were bought by settlers who had not previously seen them, and this probably accounts for the fact that the first land to be alienated included low-class as well as high-class country. This applied, for instance, to a colony of Germans who settled around Harkaway, on country consisting largely of uninviting hills of granodiorite.

After partly clearing their blocks, the settlers started by growing crops, especially wheat and barley, which were the most profitable cash crops at the time. Wheat on the basaltic country north of Berwick originally yielded as much as 50 bushels per acre. A flour mill was also built at Berwick about this time.

During the sixties the price of wheat and barley fell, and rusts began to infect the wheat, which then consisted of non-resistant varieties such as White Tuscan and Purple Straw. There was accordingly a rapid change from cropping to dairying and mixed farming, for which also the freshly cleared land was used. Since then dairying has been the most important industry in the district.

The population of the district increased rapidly during the late fifties and early sixties, and a township sprang up at Berwick, where a post office, churches, and public halls were built about this time. The first schools were privately owned but a State school was opened in 1859. The district of Berwick was created a shire in 1868, and its progress since then is summarized in Table III.

TABLE III.—SHIRE OF BERWICK, 1880-1937.

Year.	Area in Square Miles	Population.	Number of Dwellings.
1880	312	3,200	..
1890	300	4,700	..
1900	387	6,500	..
1910	387	6,430	1,400
1920	384	7,900	1,600
1930	384	9,400	2,355
1937	384	9,700	2,550

This early settlement extended as far east as Cardinia Creek. To the south of the Prince's Highway and east of Cardinia Creek, settlement first took place in the seventies and eighties. Originally this land was used mostly for grazing sheep and beef cattle but dairying now plays a more prominent part. In the stony and hilly country east of Cardinia Creek and north of the Highway, settlement started considerably later; in fact, apart from the few orchards, much of this country though alienated is still not even cleared.

The surveyed district is close to Melbourne, and the lightly timbered flat to undulating country (especially in the south) was cleared at comparatively low cost. The district was favourably situated therefore for the supply, first of dairy butter and eggs, and later of wholemilk also, to Melbourne. Before the introduction of the cream separator about 1890 the butter was manufactured on the farms. The early German settlers around Harkaway walked along bush tracks to Melbourne with the home-made butter and eggs and sold them in the market. As better roads were made, carts and drays were used for transport, and eventually the railway. With the development of butter factories and of refrigeration on ships, the export of butter rapidly became an important industry which gave a good return to the dairy farmer supplying cream for manufacture into butter. In spite of this the dairy farmer in this district has long considered that supplying wholemilk to Melbourne is more profitable than producing cream for butter.

The development of the sheep and beef cattle industries in this district has been less striking than that of dairying. Close proximity to the metropolis is not so valuable to these industries as it is to dairying. However, there have always been a number of farmers in this district who derive part or all of the farm income from sheep, grown in former years for their wool but in recent years mainly for the sale of fat lambs.

More recent developments have been the planting of scattered apple orchards in the hills, mostly between 1915 and 1922, and various attempts at closer settlement, which are dealt with in a later section.

The price at which land changes hands naturally varies with individual cases, but farmers in the district have paid about £13 an acre during 1937 and 1938 for unimproved property under native grasses.

Definition and Distribution of Farm Types.

For the purposes of this survey 192 farmers were considered in detail. (The word "farmer" is used in a general sense in this paper, and includes the term "grazier.") This figure includes every one whose holding is not less than 20 acres. Information was not complete for all of these men; on this account, some of the group totals in the following Tables (as in Table VI.) fall short of the totals given in Table IV. The various types of farming, as discussed here, and as summarized in Table IV., are defined as follows:—A *dairy farmer* is one who milks a herd averaging more than eight cows, and who derives more than 80 per cent. of his farm income from dairying. Similarly, *sheep*, and *beef cattle and agistment farmers* are those deriving more than 80 per cent. of their farm income from these respective occupations. A *mixed farmer* is one who derives more than 20 per cent. of his farm income from each of at least two types of farming; usually sheep and dairying. *Orchardists* are those who derive at least 80 per cent. of their farm income from the sale of fruit. The *miscellaneous* group includes all other persons whose holdings exceed 20 acres, but who could not be classified according to the above scheme. This class is composed mainly of market-gardeners and flower-growers, and persons who work as labourers in addition to owning a small property.

Table IV.—Distribution of Farmers on Basis of Occupation and Size of Holding.

Size of Holding (Acres).	Number of Farmers of Given Occupation.						
	Dairy.	Sheep.	Mixed.	Beef Cattle or Agistment.	Orchardists.	Miscellaneous.	Total.
20–99	38	4	1	1	22	21	87
100–199	33	3	7	4	2	6	55
200–299	8	6	5	4	..	1	24
300–399	4	4	3	..	..	..	11
400–599	2	1	6	..	..	..	9
>600	1	4	1	..	..	..	6
Total farmers ..	86	22	23	9	24	28	192
Total acres ..	12,040	6,850	7,420	1,580	1,140	1,980	31,010
Percentage of Total Area	39	22	24	5	4	6	100
Average size of farm in acres	140	311	321	176	48	71	162

FIG 7. MAP OF BERWICK AREA SHOWING LAND USE.

The distribution of the various types of farm is shown in fig. 7. The land mapped as *unproductive* is covered with "Peppermint" timber (*Eucalyptus australiana*) or is useless because of dense bracken or rushes. It will be seen that the farm types are scattered more or less at random over the area. Comparison with the soil map (fig. 6) indicates that apart from the orchards, which are confined to the Silurian foothills, soil type is not correlated with the type or size of farm. This is partly because cash crops like potatoes, which might force dairying and grazing off the better soils, are not grown here, and partly because even such inherently poor types as Toomuc sandy loam carry good pasture if well managed. Nor does there appear to be any relationship between the distribution of particular farm types and main roads, as might be presumed in the case of dairy farmers supplying whole milk to Melbourne. This is not really surprising since there are fine highways and a close network of fairly good side roads, and the dairy farmers are willing to transport milk to the highways if necessary.

The area within the boundaries of the map (fig. 7) is 40,170 acres, of which 31,010 acres are occupied by men who are actively engaged on the land and 2,550 acres are taken up by roads, townships, &c. Most of the remaining unproductive land lies in the rugged hills in the north-east of the area, where 5,200 acres are under native timber.

SYSTEMS OF TENURE AND LENGTH OF TENURE.

The systems of tenure under which the properties are conducted are shown in Table V. In this classification "owned" properties are not necessarily freehold; many of them are being bought under long-term "hire purchase" agreements. Rentals for leased properties vary from about 15s. to 30s. per acre per annum, depending on the type of country and the extent to which it has been improved. A few farmers in addition to

TABLE V.—DISTRIBUTION OF FARMERS ON BASIS OF SYSTEMS OF TENURE.

System of Tenure.	Number of Farmers of Given Occupation.						
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Orchardists.	Miscellaneous.	Total.
Ownership	61	19	22	8	24	24	158
Leasehold	21	3	..	1	..	4	29
Sharefarmers ..	4	..	1	..	..	..	5
Total farmers ..	86	22	23	9	24	28	192
Owned farms as percentage of total ..	71%	86%	96%	89%	100%	86%	82%

NOTE.—"Owned" farms include those which are being bought under long-term hire-purchase agreements.

owning their property also lease part, or all, of an adjoining property, for grazing dry dairy cows, sheep, or beef cattle. Of the 192 properties considered, 158, or 82 per cent., are owned by the present occupiers. It is noticeable that all orchards are owned by the occupiers, whereas only 70 per cent. of dairy farms are so owned.

Table VI shows the length of time each property has been held by the present farmer or by his family. These figures indicate the extent to which land has been changing hands over the

TABLE VI.—DISTRIBUTION OF FARMERS ON BASIS OF LENGTH OF TENURE.

Number of Years on this Property.	Number of Farmers of Given Occupation.						
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Orchardists.	Miscellaneous.	Total.
0-2	22	9	..	..	..	7	38
3–4	19	1	2	..	2	3	27
5–9	12	6	3	3	4	3	31
10–14	7	1	3	1	3	3	18
15–19	9	1	4	1	3	..	18
>20	15	3	10	3	10	4	45
Total	84	21	22	8	22	20	177

NOTE.—For a property worked on the share basis, the figure refers to the owner and not to the share-farmer.

past few years. Only about half of the dairymen, sheep farmers, and miscellaneous group have been here longer than five years, and about one-third have been longer than ten years. Orchardists and mixed farmers are obviously the most stable, 45 per cent. having been here longer than twenty years. This movement of farmers is probably associated with inflated land values and the immobility of orchardists is possibly due to general depression in the industry. Fifteen per cent. of the properties are held as leasehold. Several of the owners of these properties are descendants of original selectors, and are living in retirement in Melbourne. It is obvious that leasehold is not a stable arrangement—for example, among the dairy farmers, only 1 in 20 of lessees (5 per cent.) has been here as long as ten years, compared with 45 per cent. for owners. The chief drawback of the leasehold system is lack of security of tenure, in consequence of which there is little incentive for the tenant to improve the pastures, buildings, fences, and water supply; in fact, much more top-dressing is done on "owned" than on "leased" properties.

The number of share farmers (5) is too small to allow any conclusions to be drawn.

SIZE OF HOLDINGS.

As shown in Table IV, the size of holding varies with occupation, from an average of 48 acres for orchardists to an average of 321 acres for sheep farmers. The large proportion of dairy farms in the smaller size-groups is noticeable; 82 per cent. of dairy farmers have less than 200 acres, compared with 37 per cent. of all other graziers (sheep, cattle, and mixed farmers). These figures must be qualified by the following facts:—(*a*) Sixteen farmers have land outside the area in addition to that within the area; and (*b*), four farmers own more than one property within the area, but we have counted each farm as a unit. About 10 per cent. of the land included in this table is unproductive, being covered with bracken, scrub, or timber, which is only slowly being cleared.

PASTURES.

The pastures may be divided into three classes:—(*a*) Unimproved native pastures which took possession after the timber was cleared, and in which kangaroo grass and wallaby grass are dominant; (*b*) improved but low-grade pastures, in which subterranean clover and perennial rye grass occur together with high percentages of inferior grasses and flatweeds; and (*c*) highly improved pastures, comprising perennial rye grass, subterranean clover, white clover, and cocksfoot. The areas of these classes were estimated by inspection on the various properties, and are summarized in Table VII. The relative importance of the last-named class (at present 23 per cent. of the total) is rapidly growing. It is rather higher among those grazing sheep and beef cattle than among the dairymen. The difference between the figures for total grassland and total area includes cropland (about 1,500 acres) as well as unproductive land.

TABLE VII.—CLASSIFICATION OF PASTURES.

—	Acreages Held by Owners of Given Occupation.					
	Dairy.	Sheep.	Mixed.	Beef Cattle.	Miscellaneous.	Total.
Unimproved native	3,800	2,130	2,100	520	990	9,540
Improved but low grade ..	4,110	2,670	3,070	420	270	10,540
Highly improved	2,080	1,780	1,590	560	40	6,050
Total pasture	9,990	6,580	6,760	1,500	1,300	26,130
Pasture top-dressed annually ..	6,230	5,000	5,140	1,100	220	17,690
Total area of properties ..	12,040	6,850	7,420	1,580	1,980	29,870
Number of farmers	86	22	23	9	27	167

Topdressing and Improvements.—An area of 17,690 acres, or 70 per cent. of the area under pasture, is now top-dressed each year at an average rate of 140 lb. per acre. If the 86 dairymen are grouped with fourteen mixed farmers with whom dairying is an important activity, to give a group of 100 farms carrying dairy cows, the properties on which less than 50 per cent. of the farm is top-dressed carry one stock unit per 3.4 acres, compared with an average of one stock unit per 2.0 acres for properties on which more than 50 per cent. is top-dressed. Most farmers top-dress their pastures in the autumn, but some of those who use large amounts of superphosphate apply part in autumn and part in spring.

Thirty-five per cent. of the pastures are harrowed annually, generally before topdressing in the autumn. On many farms it was obvious that more harrowing was necessary for the purpose of spreading cow manure.

There are two alternative methods of improving the native pastures. The pasture may be ploughed up and one or two crops, usually oats, rape, or maize may be grown, and in the following autumn a mixture of grasses and clovers sown down—mainly perennial rye grass and subterranean clover. This method is the more expensive but it leads to a first-class pasture quicker than the alternative method, which is to give the rough native pasture a vigorous harrowing and then to sow a few pounds of a mixture of subterranean clover and perennial rye grass, and to repeat this process annually for two or three years. In this way by annual topdressings of one to one and a half cwt. of superphosphate per acre the pasture is gradually improved, and after five or six years the fertility is raised to such an extent that perennial rye grass and white clover persist. This method is less expensive and in the long run it produces as good a pasture as the other, the native grasses being unable to withstand the competition of plants which flourish under the conditions of higher fertility.

Pasture Species.—Subterranean clover and perennial rye grass are the two outstanding plants in the better pastures in this district. Other useful pasture plants, however, have their place, and white clover is the most important of these. Cocksfoot is important on a few properties, particularly on the hills. Strawberry clover does well on the heavier soils along depressions in the flatter country to the south. A few farmers have successfully combined subterranean clover with paspalum (*P. dilatatum*) which makes its growth during the summer after the subterranean clover has died. Other introduced species such as Yorkshire fog, crested dogstail, and sweet vernal thrive in this district, but their value is doubtful. It has been suggested in neighbouring districts that *Phalaris tuberosa* should be introduced on the clay flats, since it could be particularly effective in protecting the soil from puddling by cattle during wet winters. This grass does not appear to be used here as yet.

Chemical Fertility.—1. Phosphorus and nitrogen.—The inherent fertility of the lighter soils is low, and that of the heavier soils on the basalt and on the flats was seriously depleted in earlier years. For 60 years the soil was exploited and no artificial fertilizers were used on the grazing land. Topdressing with superphosphate started about 1920 but was not carried on extensively until 1930, and its use is still increasing rapidly—in fact, over the past three years the total area topdressed has increased by 30 per cent.

The general experiences on the coastal soils in Southern Australia which have been impoverished by centuries of heavy rainfall, is that the fertility must be built up by annual applications of superphosphate combined with subterranean clover, which adds nitrogen to the soil in a readily available form. The Victorian Pasture Improvement League (hereafter referred to as V.P.I.L.) has set up a series of experimental plots at Pakenham, just outside our area, on land very similar to the Hallam loam within the area; the observations made on these plots confirm the general experience of the district, that superphosphate results in a greatly increased growth and is the fundamental fertilizer on this country.

The status of phosphorus and nitrogen in the soil is thus brought to a satisfactory level by the combination of superphosphate and clover. Two other elements, potassium and calcium, are also of interest as possible limiting factors in production.

2. Potassium. The experiments of the V.P.I.L. in the Western District of Victoria have shown that on certain light podzolic soils the growth of pasture is much increased by potash salts. Many podzolic sandy loams in our area are very low in available potassium, and it would not be surprising to find a response to potash on those properties that have been heavily cropped in the past. As yet, however, there is no positive information on this point.

3. Calcium. The whole of the country to the south of the highway, except for the few basaltic ridges, was formerly notorious for "cripples" in stock. This disease appears to be a malformation of the bones due to a lack of calcium. The trouble has disappeared from the district since the introduction of superphosphate, which thus appears to have acted as a source both of calcium and of phosphorus.

Great interest has been aroused by the possibilities of lime. The usefulness of lime on these pastures is still a controversial matter, but apart from some highly acidic patches lime does not increase the growth of grass, and, of course, if lime is applied it can only be considered as supplementary to superphosphate and not a substitute. Though there is no evidence that lime increases the yield of pastures, farmers of sound observation state that the stock prefer limed to unlimed pastures and are generally healthier on limed land. It seems likely that, if this is true, it is due to the provision of the necessary element calcium rather than to the neutralizing of acidity. The applications of lime have been light, of the order of two to three cwt. per acre.

Near Cranbourne in the sandhill country is a patch of 10 acres of land so intensely acidic (pH 3.1 to 3.5) that it will not even support subterranean clover, which is the most tolerant to acidity of all good pasture plants. Pot tests carried out at the School of Agriculture on samples of this sandy soil showed that about one ton per acre of lime was needed before subterranean clover and rye grass could persist. Such extremely acidic soil, however, is exceptional, and is not likely to be found in more than a few small patches.

Seasonal Growth.—Pastures produce a marked maximum of growth in the spring in this district, as elsewhere in southern Australia. The yields obtained on the experimental plots of the V.P.I.L. at Caldermeade are of interest in this respect. (Caldermeade is about 12 miles south-south-east of Pakenham, and is the only station of the V.P.I.L. making quantitative measurements which is near our area.) The pastures here are cut at convenient intervals and weighed; and the yield between mid-August and mid-November regularly amounts to two-thirds of the total for the year. Further, the yield in early summer (to the end of December) accounts for more than half of the remainder. The surveyed area probably shows an even sharper maximum in spring than does Caldermeade, where conditions are more favourable for growth into the summer. Dairymen supplying whole-milk to Melbourne have to meet the milk contracts all the year round, and hence it is desirable to overcome the effects of these major fluctuations if possible. The obvious way to do this is to conserve surplus pasture growth in late spring for use in the winter months when pastures are almost dormant. Conservation of meadow hay therefore constitutes a very important phase of the operations on the average dairy-farm. Sheep and cattle graziers usually stock more heavily during the spring flush, rather than conserve surplus growth as meadow hay. The various forms of supplementary fodder used on the farm may now be considered in turn.

FODDER CROPS.

Meadow Hay and Oaten Hay.—Fifty-eight dairy farmers grow oats, covering 660 acres and yielding about 1,200 tons. The varieties usually grown are Algerian for hay and Mulga for green feed. Except for these dairymen, oats are hardly grown at all, and the dairymen themselves have been steadily substituting meadow hay for oaten hay over the past few years.

Table VIII expresses the total hay (oaten and grass) conserved on properties in terms of cwt. per stock unit. The mean figure on the dairy farms is 16 cwt. per stock unit; on these

TABLE VIII.—DISTRIBUTION OF FARMERS ON BASIS OF CWTS. OF HAY CONSERVED PER STOCK UNIT.

Cwts. per Stock Unit.	Number of Farmers of Given Occupation.					
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Miscellaneous.	Total.
0	12	11	7	7	23	60
1–5	11	5	5	1	1	23
6–10	17	3	5	1	1	27
11–15	27	2	3	..	..	32
16–20	11	..	1	..	..	12
21–30	4	..	1	..	..	5
>30	4	..	..	..	2	6
Total	86	21	22	9	27	165

farms milking cows are given practically all the hay so that the figures underestimate the amount of hay conserved per milking cow. Only cautious conclusions can be drawn from the analysis of data collected because the figures are very approximate. This is due to the fact that the acreage of meadow hay cut and the yield per acre vary enormously from farm to farm and on any one farm from year to year. It appears that the average yield of meadow hay is about 25 cwt. per acre in the normal season. Table VIII shows that 36 per cent. of the total farmers conserve no hay and another 36 per cent. conserve each year between 1 and 15 cwt. per stock unit. This table shows how conservation of hay is almost confined to dairymen and mixed farmers, and even on the mixed farms the hay is conserved mainly for feeding dairy cattle.

It appears that even on dairy farms the amount of hay conserved is usually only sufficient to meet the normal winter requirements and there is very little reserve to cope with abnormally dry conditions such as those experienced during 1938. On all other types of farm the farm income could be increased considerably by conserving at least some of the surplus growth of the pastures in spring for the supplementary feeding of stock during the periods of limited pasture growth.

Green Crops.—The main crops under this heading are maize and millet grown for dairy cows, and rape, millet and mustard for sheep and fattening lambs. In favourable seasons oat crops are sown early in the autumn and give some useful winter feed to milking cows, as well as providing hay later in the year.

The acreage of maize and millet has decreased considerably over the past few years. This decrease may be correlated with pasture improvement. After ploughing up rough native pasture farmers would grow maize, millet, oats or rape for two or three years before sowing down to permanent pasture. Most of the productive area has now been treated in this way and farmers do not like ploughing up good pasture for the purpose of growing green crops or oaten hay.

Maize and millet are confined to 67 of the 100 farms on which dairying is a major activity. The respective areas under these crops are 430 acres and 300 acres; the total area works out at about 1 acre per three milking cows. By far the greater amount of these crops is chaffed with meadow hay and fed in the bails though on some farms the maize is cut and strewn in the pasture paddocks and the millet fed off. In addition to maize and millet, small areas of other crops such as mangolds, sudan grass and oats for green feed are occasionally grown.

About 25 per cent. of the sheep men grow some rape (usually 10 to 20 acres each) for fattening lambs and "topping off" store sheep, but this is the whole sum of the green crops grown by graziers.

Ensilage.—Only 5 per cent. of the farmers make ensilage of any description. Crops used for this purpose include maize and surplus pasture growth of all types. The silage is usually made in stacks, rather than in silos or pits.

Fodder Bought.—A great deal of fodder is bought for the supplementary feeding of milking cows during the periods when pastures are making little growth. Most dairymen rely to some extent on hay and green crops grown on the property and buy additional fodder according to the season. The quantities of such purchases are very variable. The weather was abnormally dry in 1938, and pastures made very poor growth. Hence farmers bought very large amounts of feed (mostly brewer's grains, bran, pollard, and chaff) in an attempt to maintain the milk supply of the herd and fulfil the contracts.

AMOUNT OF STOCKING AND INTENSITY OF STOCKING.

For the consideration of these two phases a stock unit was taken as one milking cow and factors were then adopted to convert other types of stock into stock units. The factors used are shown attached to Table IX, which indicates the number of stock units per farm. This number is, of course, considerably larger on the sheep and mixed farms than on dairy farms since the former are much bigger farms. However, dairying is represented by a greater total number of stock units than any other occupation in this district.

TABLE IX.—DISTRIBUTION OF FARMERS, EXCLUDING ORCHARDISTS AND MISCELLANEOUS GROUP, ON BASIS OF NUMBER OF STOCK UNITS PER FARM.

Number of Stock Units per Farm.	Number of Farmers of Given Occupation.				
	Dairy.	Sheep.	Mixed.	Beef Cattle and Agistment.	Total.
0–15	5	2	..	..	7
16–30	23	3	1	..	27
31–45	22	..	4	2	28
46–60	18	2	..	2	22
61–75	8	..	2	1	11
76–90	4	1	1	1	7
91–105	2	7	1	1	11
106–120	1	1	2	..	4
121–150	1	1	5	..	7
151–180	..	1	2	..	3
181–210	2	1	..	2	5
> 210	..	3	4	..	7
Total Farmers ..	86	22	22	9	139
Total Stock Units ..	4,020	2,630	2,930	810	10,390

The figures in the above table have been calculated using factors as follows:—One "stock unit" comprises 1 dairy cow, 1 dry cow, 1 heifer or steer over 9 months old, 1 horse, 2 calves under 9 months old, 10 sheep, or 15 lambs.

As may be seen from Table X, 60 per cent. of farmers carry stock at the rate of between 1.5–3 acres per stock unit. This table also shows that on the smaller properties (less than 100 acres) the intensity of stocking is greater than on the larger properties. The intensity of stocking is not markedly correlated with occupation, but it is highly correlated with the degree to which pastures have been improved and top-dressed. A particularly interesting fact is the absence of any connexion between carrying capacity and soil type on the more improved properties. Prominent farmers agree with our observations that with intelligent management the poorer podzolic types will carry as much stock as the richer basaltic types.

TABLE X.—DISTRIBUTION OF FARMERS, EXCLUDING ORCHARDISTS AND MISCELLANEOUS GROUP, ON BASIS OF ACRES OF PRODUCTIVE LAND PER STOCK UNIT AND SIZE OF HOLDING.

Acres of Productive Land per Stock Unit.	Number of Farmers Holding Acreages as Below.						
	20–99.	100–199.	200–299.	300–399.	400–599.	> 600.	Total.
< 1·5 ..	3	1	3	1	...	..	8
1·5–2·0 ..	14	1	3	..	1	..	19
2·0–2·5 ..	14	8	6	3	1	2	34
2·5–3·0 ..	9	9	5	2	2	1	28
3·0–3·5 ..	7	11	4	2	1	1	26
3·5–4·0 ..	1	6	1	1	1	1	11
4·0–5·0 ..	2	4	2	..	..	..	8
5·0–6·0 ..	2	2	..	..	..	..	4
Total	52	42	24	9	6	5	138

MISCELLANEOUS.

Subdivision.—The extent of subdivision ranges from an average of seven paddocks per property of less than 100 acres, to sixteen paddocks per property of more than 400 acres.

Water Supply.—The main source of water for stock is from dams. In addition many properties are served from water reticulated or fed direct from the two large creeks (Cardinia and Toomuc) running through the area. About 30 farmers have tapped the Mornington Peninsula Pipe Line; this, of course, ensures a permanent supply of water. In the flat and undulating country to the south many farmers have sunk bores and generally obtained an excellent supply of permanent water, at depths ranging from 30 to 80 feet.

Approximately a quarter of the farmers have an inadequate supply of water; that is, insufficient to cope with normal requirements during an average summer. Another quarter have a fairly good water supply from dams and creeks which is sufficient to cope with a normal summer but may fail during abnormally long periods of dry weather. About half of the farmers have a permanent supply of water; this includes farmers who have tapped the main pipe line and those who have a frontage on either Cardinia Creek or Toomuc Creek, and also about twenty men (mostly in the south) who have a more or less permanent supply of bore water.

Machinery.—The number, type and standard of implements on each property varies greatly. On practically every property apart from a few leasehold and "miscellaneous" farms, there are sufficient implements to carry out routine farm work such as ploughing, cultivating, sowing of crops and top-dressing. However, many farmers do not possess the implements necessary for making hay and do this work either by contract or with borrowed machinery. A development over the past three or four years has been the introduction of the sweep in haymaking. On most farms horses provide the power necessary for doing the farm work.

Windbreaks.—Bleak winds associated with antarctic storms occasionally blow from the westerly quarter during the colder months of the year. The chilling effect of these winds probably reduces the output of the dairy cows during the winter, and there is a risk of losing sheep after shearing in the spring through a sudden spell of cold wind. However, the desirability of plantations to serve as windbreaks for the stock in the paddocks has been appreciated only during the last few years. About 60 per cent. of the properties to-day carry plantations of fast-growing trees such as cypress.

CLOSER SETTLEMENT.

Since the early twenties the Closer Settlement Board has been active in buying land in various parts of Victoria, for the purpose of settling returned soldiers and others who could not otherwise afford to buy a property. Much of this land in Southern Victoria was divided into holdings of 100 acres or more, on which an efficient settler could dairy successfully. Other areas were cut up into smaller blocks (10 to 30 acres) designed for market gardening. These holdings were made available to settlers under long-term agreements which were more generous than the private purchaser would receive.

There have been three such areas in the district under survey. One of these areas was situated 1½ miles south-east of Officer but settlement did not take place and the small blocks reverted to larger holdings. A second, at Narre Warren North, has been fairly successful, and several flower-growers and market-gardeners are established there to-day. The third and largest undertaking was in Hallam Valley (see map, fig. 7, for boundaries within our surveyed area). This was one of the unsuccessful attempts at closer settlement in Victoria, and is considered here in more detail.

Hallam Valley Settlement.—The State Rivers and Water Supply Commission was responsible for the subdivision in Hallam Valley in 1927. The subdivided area runs just south of, and almost parallel to, the main Gippsland railway line, from Hallam station to Berwick station. The area here surveyed includes only sections 3A and 4 of this scheme. These are identical with allotments 25 and 26 in the Parish of Berwick, which were sold to the State Rivers and Water Supply Commission in 1924 for £15 to £18 per acre. This price reflected the optimism of the period, since the flat country was covered with dense tea-tree and was periodically waterlogged, while the rising land, which was naturally poor, had been cleared of timber but not otherwise improved.

The Commission cleared the swamp area of scrub and subdivided the land. The part in which we are here interested, comprising 1,153 acres, was cut up into 67 blocks, on most of which houses were built. The area of these blocks ranged from 12 to 26 acres, with an average of 17 acres; this small size was suitable for the intended occupation, namely, growing vegetables.

Two large drains were constructed through the settlement to carry off flood waters and natural drainage. The effectiveness of the drains was increased by the construction of levee banks. In addition, on the flatter and wetter parts of the settlement sub-surface drainage was assisted by 3-in. pipe drains. A network of roads was constructed and some were equipped with concrete drains. As the settlement was principally designed for market gardening, a system of water-supply pipes was installed on many blocks. Water was obtained by tapping the main pipe-line of the Mornington Peninsula water-supply scheme. The total capital cost of all these improvements was added to the initial cost of the land, bringing the cost to the settler to about £60 per acre in some cases.

The history of the settlement was disastrous. Within three years settlers were leaving, and by 1936 none of the original settlers remained. On the original 67 blocks there are now 32 houses only. Most of the holdings reverted to the Closer Settlement Board, and many of them have been resold; six farmers to-day own 35 former blocks between them. One is a market gardener, the others are small dairy farmers and apparently are quite successful. This grouping of blocks into dairy farms of 60 to 90 acres would appear to be the ultimate fate of this settlement. Several of the small blocks are vacant at present, and a few are held by men running poultry in small numbers The rest of the houses are occupied by invalid soldier pensioners who may run a few cattle on agistment but otherwise do not use the land.

In reviewing the causes of this failure, one must recognize that market gardening requires an exceptional amount of knowledge and skill. The special features of districts around Melbourne in this respect have not yet been described in a publication, but it is certain that there is a great deal of special information which is jealously guarded by many of the producers. Without such special knowledge success would be achieved only by the painful process of experimentation based on trial and error, and it appears that the settlers had little previous experience. It would have been difficult for them to pay for water and to meet the high interest charges during such a period of trial. Further, while low prices were mainly responsible for the failure, there were local problems, associated with the two soil types which are found here—namely, Hallam loam (p. 189) on the rises and the strongly contrasted Eumemmering clay (p. 191) on the reclaimed swamp.

Hallam loam is a grey podzolic soil of low fertility, being poor in several essential elements. Moreover, it has a silty texture and tends to set to a hard surface after being saturated with water. It is, of course, common for market gardeners to work with poor and light soils and to add large amounts of fertilizer and manure, and in fact there are many successful vegetable growers nearer Melbourne whose soils are similar to Hallam loam. However, the land at Hallam Valley has no advantage to offset its greater distance from the city. The value of the land is also diminished by concentrations of salt on many of the lower slopes. The patches of salty land are larger and more numerous than elsewhere in the district, one patch covering about 10 acres.

The chemical fertility of Eumemmering clay is not low by Victorian standards. Its physical properties, however, lead to difficulties in working the soil. As with other clayey soils, expert judgment is needed in choosing the right degree of moisture for a cultivation. In a wet winter the soil remains permanently wet and gets badly puddled. The subsoil consists of such impermeable clay that the drains at a depth of 3 feet are not at all efficient. Since the soil retains large amounts of water, the loss of heat involved in the evaporation of this water in spring and summer keeps the temperature of the soil relatively low. On this account early crops are not possible, and vegetables come on the market in competition with all other mid-season or late districts, when low prices often prevail. In such conditions, only the most favoured localities can remain in production, and this area does not seem to have any competitive advantage over districts at a similar distance from the city. One naturally compares this area with the reclaimed swamp land round Kooweerup, which is a major source of mid-season vegetables for Melbourne and is a few miles further away. The better soil types of Kooweerup, however, are much superior to the Eumemmering clay.

V. Land Utilization: (B) Individual Occupations.

Dairy Farmers.

There are 86 farmers who derive more than 80 per cent. of their farm income from dairying. In addition, fourteen of the mixed farmers derive a considerable part of their farm income from dairying, and hence 100 farmers, or more than half the total in the district, are to some extent dairymen. These 100 "dairy farmers" are considered together in this section except in Table XI., which refers to the activities of the 86 full-time dairy farmers.

Table XI.—Distribution of Dairy Farmers on the Basis of Number of Milking Cows and their Percentage of Total Stock Units.

Number of Milking Cows.	Percentage of Total Stock Units.							Number of Farmers
	0–39.	40–49.	50–59.	60–69.	70–79.	80–89.	90–100.	
0–9	..	..	..	3	2	..	..	5
10–14 ..	..	..	3	2	..	1	..	6
15–19 ..	..	..	3	6	6	2	..	17
20–24 ..	..	1	1	6	..	..	..	8
25–29 ..	..	..	4	5	3	2	..	14
30–34 ..	..	2	4	4	4	2	..	16
35–44 ..	..	1	1	2	2	1	..	7
45–54 ..	..	..	3	4	1	..	1	9
55–74 ..	..	..	1	..	..	..	..	1
75+	..	1	..	1	1	..	..	3
	0	5	20	33	19	8	1	86

Size of Herd.—It will be seen from Table XI. that the predominant size of herd is 15–35 cows, and that the milking cows make up between 50 and 80 per cent. of the total stock units. The totals for the 86 dairymen are 2,504 cows and 4,020 stock units. The average size of herd would be little affected by including the full 100 dairymen in this table.

Stock Diseases.—There is not much detailed information available about stock diseases but evidently disease is not a major factor. In the interests of public health the Milk Board keeps a strict supervision over the source of Melbourne's milk supply. It is, of course, known that contagious abortion, mastitis, and tuberculosis do occur, but farmers are naturally reticent in giving information.

Breeds, Herd Improvement and Yields.—There are only two pedigree herds (both Jersey) amongst those considered. Most of the cows are mixed dairy types with a very large proportion of Jersey blood. Thirty-four of the farmers use pedigree bulls of which 21 are Jerseys and 9 are Guernseys. The remainder use bulls of mixed ancestry, usually with Jersey predominating.

A peculiarity in this district is the extent to which farmers buy cows in the Dandenong Stock Market. Information supplied by farmers suggests that the average annual replacement is in the region of 20 to 25 per cent.. About 45 per cent. of farmers breed enough stock for replacement, but under the conditions of a milk contract it is essential to buy extra milkers during the winter and at any other time when production falls below the minimum set by the contract.

Ten of the farmers have their herds regularly tested for butterfat; of these seven are members of the Pakenham Herd Testing Association and the remainder test privately. Very little information regarding yields is available. However, estimates of the yields of fifteen herds (including the ten herds cited above) comprising about 500 cows show the average production to be approximately 270 lb. of butterfat per cow, per annum. These include some of the best farmers in the district, so that the average for the whole district is probably far below this figure. Thus it appears very likely that herds could be much improved by the incorporation of the progeny of tested parents bred on the property. It might be argued that this is a wholemilk district, for which butterfat tests would be of little value, but even so it is surprising that farmers should not even weigh the milk of the members of the herd.

Milking Machines.—Only ten of the farmers use milking machines. Eight of these use a 3-unit plant, but two farmers with large herds have 5-unit plants. On the other 90 farms the milking is done by hand, in most cases by the farmer and his family. One reason that has been given against the use of machines is that some dairy retailers refuse to accept milk so obtained, since they believe that it is necessarily contaminated. Whatever truth there is in this assumption is probably due to lax methods of cleaning the plant. This does not seem, however, to be the main factor responsible for the prevalence of hand-milking. The reason appears rather to be that the initial cost of machines is high, and family labour is usually available; in fact, 85 per cent. of the total hand-milking is done by the farmer and his family, at an average of one milker to eleven milking cows. Wage ratings for dairy farm-labourers in this district are in general 25s. to 30s. per week plus keep, and it seems likely that this wage level would not be attractive to skilled men.

Pigs.—Little accurate information concerning pigs is available. Pig raising is confined to the 29 dairymen who produce cream. From the approximate figures collected it appears that these farmers annually breed and fatten one to two pigs per milking cow. This figure varies from year to year, and from one property to another, depending on such factors as the number of calves reared, the productivity of the herd, and the expenditure on extra feed, such as barley. The number of pigs fattened depends also on whether they are sold as baconers or porkers; the latter is the more usual. Some of the principles of pig management are not fully appreciated; many farmers feed only skim milk to the pigs, and do not attempt to balance the ration with cereals high in carbohydrates. It seems likely that this is one of the sidelines of the dairying industry which could be more profitably exploited.

Destination of Milk Products.—Thirty-five of the 100 farmers send all their milk to Melbourne dairies, and eleven send it to local butter and cheese factories. Twenty-five send their milk to Melbourne dairies, and sell some of their spring surplus to local butter and cheese factories. The remainder (29) keep pigs and sell cream to local or suburban butter factories. The local butter and cheese factories pay for wholemilk on a butterfat basis, paying slightly more per unit of butterfat for milk than for cream. This small margin, it is claimed, compensates for loss of profit from pigs.

There is no doubt that supplying wholemilk to Melbourne pays better than selling cream, or than supplying wholemilk to local factories. However, the former system has several drawbacks, the chief of which is the expense incurred through buying extra feed and also extra cows during the winter months to maintain the production above the minimum required by the contract. It is very desirable to do this, as the Melbourne retailer throughout the flush period in the spring and early summer commits himself to accept only as much milk as was supplied on the average throughout the winter. By bringing cows into production all the year round, and by buying more cows during the winter, the wholemilk producers avoid the necessity of having to sell a large spring surplus to the butter factories. Second in importance probably are the regular and often inconvenient hours which have to be kept because the milk has to be ready when the milk wagon calls. Thirdly, such dairy farmers have to work all the year round, and cannot "dry off" most of the herd during the winter months. Fourthly, fodder taints, such as that attributed to subterranean clover, give difficulty during the spring. Such taints are much more serious in wholemilk than in cream supplied to a butter factory. These and other minor factors tend to make the costs of producing wholemilk for the Melbourne supply considerbly greater than the cost of producing cream for manufacture into butter, but the increased returns much more than compensate for this.

Conclusions.—To sum up, it appears that the production in dairying could be considerably increased. In fact, the very lack of numerical information concerning production confirms this statement, since it shows that the breed of the cows is not being deliberately improved, and this is probably the weakest feature of the industry. The farmers do not generally breed their own cows, and those who do breed do not usually select them; if they did so select, the total production would probably be lower for the time being, and the rental value of the land may be too high to allow for the long-range policy of improving the breed.

MIXED FARMERS.

Information as to the activities of the mixed farmers is contained at various points in this paper. With two exceptions they combine dairying with sheep-raising; one combines dairying with orcharding, and one combines dairying with raising beef cattle.

SHEEP FARMERS.

General.—Information relating to the operations of sheep farmers may be obtained from the composite tables. Figures indicating the amount and intensity of stocking are not as reliable as the corresponding figures for dairy farmers because the number of stock on a sheep farm is continually changing. This is due to the fact that the farmer breeds lambs and buys "store" sheep which are sold when fat. Observations suggest that the fluctuations in numbers of sheep on the property are closely correlated with the growth curves of pasture as given in V.P.I.L. Reports. (See p. 204.) The difference between dairy and sheep farmers in this respect is that the dairymen conserve some of the surplus spring growth as meadow hay and feed it to the cattle in the winter. The sheep farmers, on the other hand, have many more stock on the property during the spring flush and sell these extra stock when pasture growth falls off.

In addition to the 22 full-time sheep farmers there are 22 "mixed" farmers interested in sheep, of whom eleven devote more than 50 per cent. of their property to sheep. Thus of 44 farmers grazing sheep 33 derive more than half of their farm income from this source. Some of these men concentrate solely on breeding and fattening lambs; others produce some fat lambs, and in addition buy and fatten store wethers and weaners. There are also some who run stud sheep. There are nine small studs of English breeds which provide sires not only for the farmer's own main flock but also for sale to other farmers in the district.

The wool clip is an important asset to all these men, but it does not constitute the main part of any farmer's income in this district, although farmers naturally pay considerable attention to the quality of the wool in their choice of breeding stock. The land has a high price, and this appears to determine its use for fattening sheep rather than growing wool. The wet and frequently bleak weather of the three winter months is also considered unfavourable to the fine-woolled breeds with their liability to footrot, though the winter here is probably less severe than in some of the wool-growing parts of the Western District of Victoria.

The Flock.—Considering the diversity of this occupation and the great fluctuations in the numbers and types of sheep on each property it is difficult to present in tabular form an accurate picture of the numbers of sheep. However, on the 44 farms considered there are approximately 22,000 breeding ewes which produce about 80 to 85 per cent. of fat lambs. In addition, about 5,000 store wethers are fattened annually. Comparison of the figures collected shows that on dairy farms the stocking is rather more intense than on sheep farms.

Approximately 80 per cent. of the sheep farmers have breeding ewes which are crossbred between the fine-woolled Merino and the meat-producing English types; the remainder have either Comeback, Merino, or English breeds of ewes. The crossbred produces a good class of wool and also stands the winter fairly well. Approximately 50 per cent. of the rams used for mating with these ewes are Southdowns; Border Leicesters are next in favour.

Wool Clip.—It is difficult to give definite information here because of the fluctuations in the number of sheep from year to year. The 1938 season was particularly unfavourable for collecting such information, because a number of sheep from Northern Victoria were being grazed in this district on agistment.

Diseases and Flock Management.—The incidence of disease is fairly low. In fact, the work associated with keeping the sheep healthy and in good order is carried out more efficiently than is the improvement of the pastures. Of the common diseases affecting sheep, footrot is easily the most important, especially on the flatter and badly drained properties. Other disorders such as liver fluke, lung worm, pulpy kidney, and blowflies cause a certain amount of trouble. The lambs are normally born from late June to August, and sold from late December to March or April. The time at which the sheep are shorn varies from early October to late November.

Beef Cattle and Agistment Farmers.

Of nine such farmers in the Berwick District, seven own their properties and run their own cattle, the other two take in agistment stock, which are mostly beef cattle. This number is too small for attempting statistical treatment, and so generalizations only can be made. However, some information on the operations of these graziers may be obtained from the various preceding Tables. The average size of holding is 176 acres; the standard of agriculture as shown by the amount of topdressing is comparatively high.

In addition to these men whose main occupation is running cattle, there are several mixed farmers who run some beef cattle, which eat the rough pasture which is not attractive to sheep. The possibility of developing the production of a small number of "baby beef" cattle on dairy farms has not been exploited, probably because the average dairy farm is just large enough to graze a herd which the owner and his family can manage efficiently.

Herefords are kept in the greatest numbers, and next in importance are Shorthorns. Most of the herds are very mixed in type, however, since they include many spayed dairy culls for fattening, also some of the beef men are interested in growing young dairy types up to the "springing stage" and catering for the large demand from local dairy farmers for milkers during periods of low production.

Most beef cattle farmers in the district agree that dairying, or even sheep farming, produces a larger cash return per acre; but, on the other hand, producing beef cattle is a much more congenial occupation.

Orchardists.

The 25 orchardists constitute only a small sample which is perhaps not representative of the many orchardists in the undulating or hilly country east of Melbourne. Most of the orchards in the surveyed area were planted between 1915 and 1922, and the majority of the present holders are the original settlers. The settlers spent much capital and energy in clearing the timber before planting their orchards. The cost of clearing was undoubtedly high, although no exact figures are available; and this cost, plus the living expenses for the five or six years during which the young fruit trees were growing and giving no return, consumed the holders' reserves or involved them in debts which were to prove a burden in the years to come.

Topography and Soils.—Orcharding is the only occupation in this district which is associated with particular soil types. Twenty-two out of the 25 orchards are on the Silurian phase of Hallam loam (described on page 189) situated on gentle to moderate slopes, and the other three are on Harkaway sand (page 187), derived from granodiorite.

Cultural Practices.—The owners do the regular work of the orchards themselves and employ very little permanent labour. They do, however, employ a good deal of casual labour for five or six weeks during the height of the picking season. The routine operations of the orchards call for little comment.

Every orchardist has, in a normal season, sufficient water for spraying. Seven out of the 25 orchardists also conserve sufficient water in dams to irrigate some of the trees. Irrigation is confined to the variety Yates as a rule, in order to get the fruit on these up to commercial size. Yates trees receive six to eight waterings during the summer, depending on the season and the supply.

The usual application of fertilizer is five or six pounds per tree of a mixture consisting of superphosphate, sulphate of ammonia, and chloride of potash, in the proportions 2:2:1. Most orchardists apply half a ton of lime per acre every two or three years. In some of the orchards the trees show only mediocre growth due to insufficient applications of fertilizer, in most cases because of the owner's lack of capital. A curious problem with which a few orchardists have to contend is the presence of land crabs or "yabbies." The crabs in the heavier low-lying flats excavate large holes (up to 30 inches in diameter) 2 or 3 feet below the surface. In wet weather the holes fill up with water and the sub-surface drainage problem is accentuated. Pouring solutions of copper sulphate down the tunnels is said to be effective against the crabs.

Size of Orchard.—The size of the holdings and the orchards is summarized in Table XII, in which one "mixed farmer" is included with those who are purely orchardists. These 25 orchardists hold 1,300 acres of land of which 370 acres are planted to orchard, 700 acres are cleared and in pasture, and the remaining 230 acres are still uncleared bush.

TABLE XII.—DISTRIBUTION OF ORCHARDISTS ON BASIS OF TOTAL HOLDING AND OF AREA PLANTED.

Distribution on Basis of Size of Holding.		Distribution on Basis of Area of Planted Orchard.	
Size in Acres.	Number of Orchardists.	Size in Acres.	Number of Orchardists.
20–40	12	3–9	3
40–60	7	9–13	10
60–80	2	13–17	4
80–170	4	17–21	5
		21–45	3

Varieties.—The most common varieties originally planted were Jonathan, Yates, and Delicious. These varieties are still very popular; but over the past six to eight years many old stock such as Reinette, Gravenstein, and Yates, have been reworked to Granny Smith. Yates has declined in popularity, partly because its good keeping qualities have become less important since cool storage developed, and partly because of the additional work involved in thinning and irrigating.

The present acreages of the several varieties are as follows:—

Jonathan	118
Granny Smith	68
Yates	63
Delicious	26
Miscellaneous—Democrat, Gravenstein, &c. ..	31
Young trees not yet full bearing	60

There are also 14 acres under pears, cherries, peaches and lemons.

Yields.—It appears that in this district there are large variations in the average yields between one orchard and another, and also on any one orchard from season to season. Fairly accurate figures for yield were available for 20 of the 25 orchards, and the average of these was 1.5 bushels per tree, or 150 bushels per acre. As some of the orchards average 2 to 3 bushels per tree it would seems that production for the district could be increased considerably.

Soil Fertility.—The natural chemical fertility of these soils is low; further, they are liable to erode, and the presence of stones up to 3 inches in length makes for difficult working, and increases the wear and tear on implements. It is a tradition in Victoria that fruit trees should be planted on poor country. The chief merit of this appears to be that the fruit from such trees keeps better in cool storage, but this hardly compensates for low yields, although other districts with somewhat similar soils and more favourable slopes have achieved a fair success.

Drainage.—Three hundred and twenty acres, or 87 per cent. of the area planted to orchards is tile-drained. The upper soil is loamy and permeable to a depth ranging from 6 to 15 inches,.

and the subsoil is a heavy clay; but many of the drains have been sunk too deeply into this clay, so that the improvement caused by drainage is not so general as one might have expected. In addition, some of the drains run in the direction of greatest slope and so lose most of their effectiveness.

Erosion.—It appears that on the stony Silurian soil, if the slope is greater than 5 degrees and the soil is cultivated there is a great tendency to erode. Since many of the orchard slopes are as steep as 10 degrees a great deal of surface soil is eroded and the fertility of the upper slopes is depleted; in fact, in some places the trees are now growing on the subsoil, all the surface soil having been washed away. It is obvious from the topography that much of this hill country should never have been devoted to a type of agriculture in which the soil is fallowed during the summer months. However, the capital has been expended and the difficulty now is how best to control erosion and increase fertility. It is said that the worst damage is done by thunderstorms in summer when the land is bare. The records for Melbourne show that a fall of at least half an inch of rain in an hour occurs on an average three times in four summers, and a fall of at least an inch in two hours occurs once in four summers. The corresponding figures for this orchard country are not known, but the frequency of heavy falls is certainly greater than in Melbourne.

Erosion can probably be minimized by cultivation along the contours instead of in the direction of the greatest slope as at present. However, some orchardists maintain that this hampers drainage, and the trees eventually die through "wet-feet." The accuracy of this latter statement has not been verified.

The possibility of planting trees along contours in order to facilitate contour ploughing, as has been advocated in other countries, has not been explored in this district.

Economic Position.—The orchardists of this district share in the general financial difficulties of the apple industry. Many of them have been particularly unfortunate, since after undertaking the heavy initial cost of clearing, draining, and planting, and providing for themselves during the five or six years while the young trees were still not producing, they were faced almost at once with low prices which did not allow them to recover their outlay. Further, while fertilizers and sprays involve a heavy annual expense, yields are generally not high, and many orchardists spend considerable labour and money in scooping back the soil that has been washed down the slopes. In these circumstances, and in view of the unlikelihood of any great rise in the price of apples, it appears that the only possible avenue of relief for many of these men is to supplement their income with sidelines. This possibility has not been exploited in the past; except for one man who is doing some poultry farming, another who has a tractor and is doing contract work for his neighbours, and two others who do some dairying, all the orchardists in this district depend almost solely on orcharding for a living. By keeping a few poultry and perhaps a few dairy cows they could increase their income substantially. It appears that if within the next few years the farm income is not increased by either higher yields or supplementary income from sidelines, then many of these orchardists must be absorbed in other industries.

Miscellaneous Farmers.

Of the 28 miscellaneous farmers only nine depend solely on their property for their income. Of these four are market gardeners, three are flower-growers, and two run poultry.

There remain nineteen holdings in this miscellaneous section, whose occupiers do not derive their main income from the property. Except for four owners who do not use their land at all, the small property is really a worker's home, and in addition provides a small income from the few dairy cows, and occasionally from stock on agistment. These men derive the rest of their income from other sources; viz., wages for work done for neighbouring farmers or for such bodies as the Country Roads Board, or alternatively from running a business in one of the local townships. As the means by which the miscellaneous farmers obtain their living are very diverse it is difficult to present in tabular form a picture of their activities. However, Table V shows that 86 per cent. of such properties are owned, and Table VI that most of the owners have been on their present properties for several years. While almost all the land held by such farmers is productive, the standard of farming is low. Pastures are poor, and there is little top-dressing or conserving fodder for the winter. This is not surprising where the owners have little capital and have other sources of income.

General Conclusions.

The area as a whole provides an example of the extent to which naturally poor country can be economically converted into good pasture land in a district of fairly generous rainfall. During the first half-century of settlement farmers increased their production by clearing fresh land rather than by intensifying production on land already cleared. More recently, however, intensification has become the rule; improvement with superphosphate and introduced pasture plants has been particularly rapid since about 1933, and is still progressing. There seems to be no reason, other than shortage of capital, why all the flat or gently sloping land should not be brought up to the carrying capacity of the better dairymen—namely, the equivalent of one cow to 2 acres; it should be possible for dairymen working at this capacity to confine their purchases of additional fodder to a protein supplement for two winter months. The present rate of stocking is approximately one cow to 3 acres. Such an improvement is independent of the further need for raising the quality of the cows.

The amount of cropping has never been great, and has declined for several years past. Heavy crops of potatoes and onions were grown in the early days on the basaltic soils, but these crops are not grown there to-day though they would probably still give good yields. The only cash crops grown in the district are small amounts of vegetables, for which this district does not seem to hold any particular advantage.

The definitely hilly country presents a different problem. This land is not suitable for agriculture, and in some places its exploitation has led to financial loss. Most of this section is probably best left under its present cover of Eucalyptus.

VI. Chemical, Physical, and Mineralogical Analyses of Soil Types.

A few samples were chosen from each main type going to a depth of 3 to 5 feet. Routine laboratory analyses were done on the various horizons of each of these typical profiles.

Mechanical Analyses.

Complete mechanical analyses were carried out on selected profiles from each type of soil. The details are given in Tables XIII to XXI, in which the percentages are in terms of oven-dry soil. The mechanical fractions are defined by the " International " limits, viz., Coarse sand, 2.0 to 0.2 mm.; Fine sand, 0.2 to 0.02 mm.; Silt, 0.02 to 0.002 mm.; and Clay, less than 0.002 mm. These figures have been recalculated to a basis of sand + silt + clay = 100, and the results are expressed diagrammatically for representative samples in Fig. 8. This diagram shows strikingly the sudden transition from the light surface to the heavy subsoil in the podzolic Harkaway, Hallam, and Toomuc types, and the

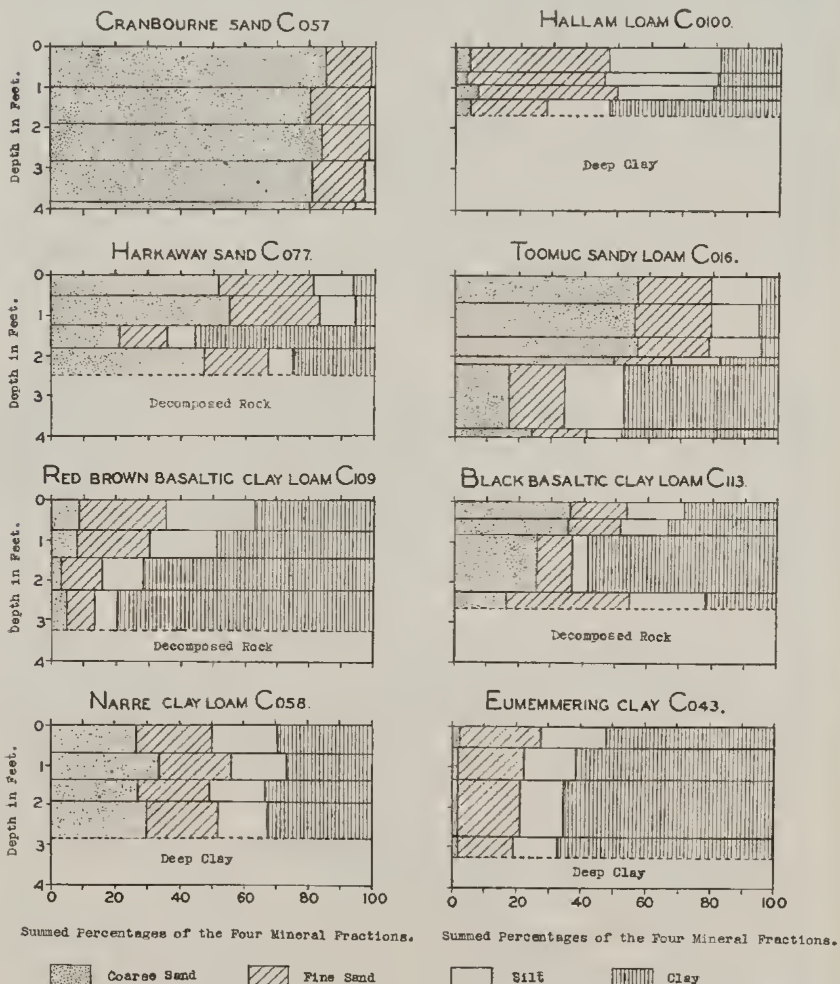


Fig. 8.—Mechanical composition showing in block form the summed percentages of the four mineral fractions throughout the profiles of eight major soil types. (Clay in Cranbourne sand is too small to show separately.)

relatively constant texture, or gradual change of texture through the profile, of the heavier Narre and Eumemmering types and the basaltic soils. The very sandy type, Cranbourne sand, also shows a large relative increase in clay in the subsoil, but the absolute quantity of clay is too small to be marked in the diagram. The ironstone gravel, which occurs above the clay horizon in many types, has been omitted from the diagram since it is not always present in the field. The diagram refers to the same material as is submitted to laboratory analysis—viz., the soil which passes a 2-mm. sieve.

Hallam loam is remarkably high in silt throughout the profile, a property which is evidently due to the silty nature of the Silurian rock from which its material has been derived. This siltiness is connected with the tendency of the surface soil to form clods, and with its erosiveness in the orchards. Harkaway sand, developed from the granodiorite, stands in marked contrast, with a low percentage of silt. This seems to indicate that the granodiorite hills have not played a considerable part in forming the material from which the silty soils of the plain were derived. Narre clay loam includes occurrences in which the subsoil is considerably heavier than in the two type samples.

A zone of maximum accumulation of clay can be seen in Cranbourne sand (C057), and on soils developed over the basalt (C113), the granodiorite (C077) and the Silurian sediments (C041).

The mechanical analyses of representative samples have also been plotted graphically in fig. 9, where the triangular method is

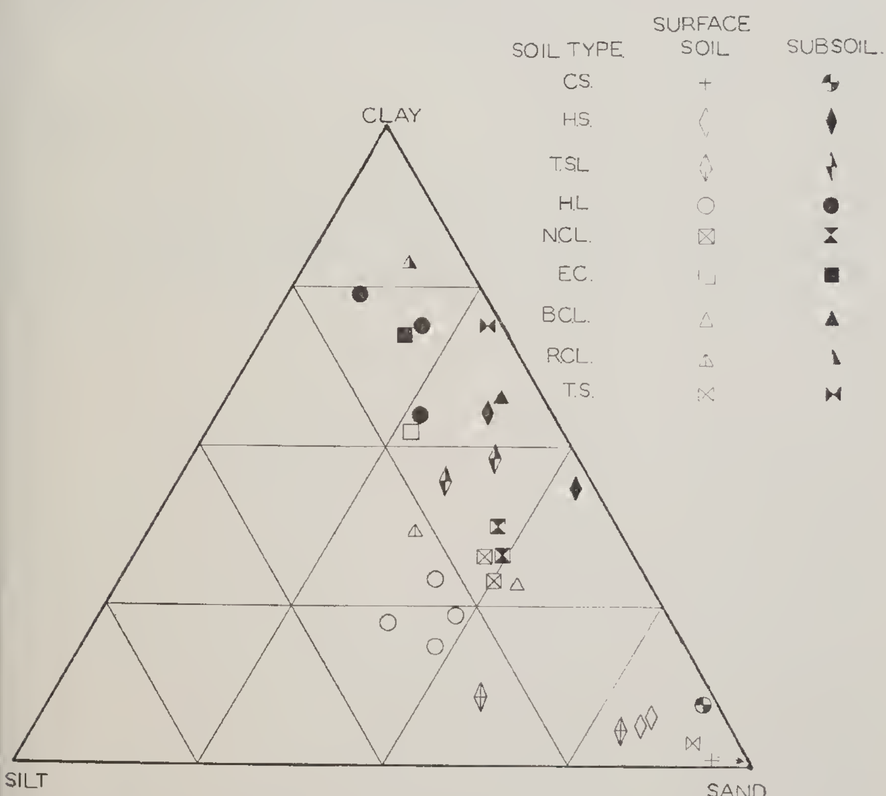


Fig. 9.—Mechanical analysis triangle. Distribution of mechanical compositions of samples of surface soil and subsoil of various soil types.

Explanation of Key.—C.S. Cranbourne Sand; H.S. Harkaway Sand; T.S.L. Toomuc Sandy Loam; H.L. Hallam Loam; N.C.L. Narre Clay Loam; E.C. Eumemmering Clay; B.C.L. Black Basaltic Clay Loam; R.C.L. Red Basaltic Clay Loam; T.S. Toomuc Sand.

adopted by which any mixture of sand, silt, and clay can be represented by a point. This shows in another way such facts as the contrast between surface and subsoil of the podzolic types (the latter lying much closer to the " clay " apex than the former) and the silty nature of Hallam loam, of which all four surface samples lie between the lines for 25 per cent. and 50 per cent. silt.

TABLE XIII.—MECHANICAL ANALYSES OF HARKAWAY SAND.

Soil No.	C013.			C077.			
Horizon	*a*†.	*b*.	*c*.	*a*.	*b*.	*c*.	d.
Depth (Inches)	0–10.	10–21.	21–32.	0–6.	6–15.	15–22.	22–30.
Coarse sand	59·2	61·3	47·6	49·7	54·1	21·3	47·5
Fine sand	22·2	22·3	6·7	28·5	27·9	14·6	19·5
Silt	9·8	8·5	2·5	11·4	10·6	8·6	7·9
Clay	7·5	6·6	43·9	6·0	5·9	55·3	24·8
Loss on Treatment* ..	3·0	1·7	1·5	4·1	1·3	1·3	1·1
Carbon	1·28	0·33	0·45	2·28	..	..	..
Nitrogen	0·11	0·02	..	..	..	..	..
Gravel (Field Sample) ..	..	..	..	..	11·1	2·3	8·5
pH	5·9	5·9	5·7	5·6	5·2	5·2	5·5
Comments	..	..	..	..	..	..	Decomposed Rock.

* This figure includes the organic matter destroyed by hydrogen peroxide in preliminary treatment, as well as the material dissolved at the next stage by dilute HCl.

† The letters *a, b, c* . . . as used here refer simply to the order of sampling of the various horizons, *a* being the first and *d* the fourth horizon to be taken in a profile. The letters are not meant to suggest any parallel with the technical meanings of *A, B,* and *C* horizons.

TABLE XIV.—MECHANICAL ANALYSES OF CRANBOURNE SAND.

Soil No.	C057.						
Horizon	*a*	*b*	*c*	*d*	*e*	*f*	*g*
Depth (inches)	0–12	12–23	23–34	34–46	46–60	60–64	64–66
Coarse sand	83·9	79·6	83·0	79·1	78·0	71·1	78·4
Fine sand	13·2	17·9	14·3	15·3	13·8	15·5	13·6
Silt	0·8	1·1	1·2	2·0	4·6	1·8	3·3
Clay	0·3	0·4	0·3	1·0	1·2	9·7	3·4
Loss on treatment ..	1·1	0·6	0·7	2·2	1·6	2·7	0·9
Carbon	0·89	0·42	..	1·05	1·05	..	..
Nitrogen	0·04	..	..	..	0·05	..	..
Gravel (field sample) ..	..	..	..	..	..	..	..
pH	4·9	4·7	4·3	4·6	4·9	..	4·8
Comments	..	..	..	..	Friable Ortstein	..	..

TABLE XV.—MECHANICAL ANALYSES OF TOOMUC SANDY LOAM.

Soil Number	C016.					
Horizon	*a*	*b*	*c*	*d*	*e*	*f*
Depth (Inches)	0–8	8–18	18–24	24–26	26–46	46–60
Coarse sand	55·6	55·2	56·7	49·3	16·9	23·9
Fine sand	22·8	24·2	22·6	18·3	17·0	17·3
Silt	14·8	14·7	16·0	14·7	18·3	11·2
Clay	5·5	6·1	5·5	18·3	47·8	48·6
Loss on treatment	3·5	1·8	1·3	1·3	1·9	1·1
Carbon	1·07	0·25	0·12	0·27	..	..
Nitrogen	0·06	0·02	..	..	..	..
Gravel (field sample)	..	..	..	..	..	..
pH	5·6	5·4	5·5	5·8	5·4	5·1

TABLE XVI.—MECHANICAL ANALYSES OF TOOMUC SANDY LOAM.

Soil No.	C092.						
Horizon	*a*	*b*	*c*	*d*	*e*	*f*	*g*
Depth (inches)	0–9	9–14	16–26	26–41	41–54	54–64	64–72
Coarse sand	14·5	23·4	16·3	21·3	9·0	12·2	16·6
Fine sand	40·0	39·8	23·8	29·6	26·7	24·5	21·4
Silt	29·6	25·3	17·3	16·0	19·6	20·6	22·1
Clay	10·2	9·7	41·9	32·2	44·7	42·0	39·9
Loss on treatment ..	3·9	1·8	1·3	1·1	1·1	0·8	0·5
Carbon	2·38	0·81	..	..	..	..	..
Nitrogen	0·15	..	..	..	..	..	..
Gravel (field sample) ..	..	..	..	..	..	..	..
pH	5·1	5·8	5·6	6·2	6·5	6·5	6·7

TABLE XVII.—MECHANICAL ANALYSES OF HALLAM LOAM.

Soil No. ..	C0100.				C041.				
Phase	Normal.				Silurian.				
Horizon ..	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*
Depth (inches) ..	0–7	7–11	11–15	15–20	0–8	8–12	12–18	18–30	30–44
Coarse sand ..	4·6	3·5	6·7	4·5	2·4	2·4	4·8	0·8	0·4
Fine sand ..	40·8	41·8	42·7	22·1	34·2	33·4	31·6	8·6	8·6
Silt	32·0	32·7	29·2	18·9	35·5	33·6	31·4	16·3	35·9
Clay	17·9	19·1	20·5	55·1	21·0	25·2	29·6	72·9	54·6
Loss on treatment	5·3	3·8	2·5	1·4	5·8	3·7	2·7	1·3	0·6
Carbon ..	3·61	2·11	..	..	3·36	1·60	..	..	..
Nitrogen ..	0·24	..	..	..	0·20	0·12	..	..	..
Gravel (field sample) ..	..	..	9·7	1·7	..	..	..	..	..
pH	5·3	5·6	5·6	5·3	4·7	4·4	4·5	4·7	4·6
Comments ..	..	..	..	Deep clay	..	..	..	..	Soft rock

TABLE XVIII.—MECHANICAL ANALYSES OF HALLAM LOAM.

Soil No.	C050.	C038.				
Phase	Normal.	Heavy.				
Horizon	*a*	*a*	*b*	*c*	*d*	*e*
Depth (inches)	0–8	0–6	6–11	11–16	16–21	21–32
Coarse sand	2·9	11·3	2·2	16·8	4·4	6·8
Fine sand	42·5	27·9	42·8	31·3	15·2	15·6
Silt	27·0	26·2	23·8	19·2	11·1	8·6
Clay	22·5	27·2	25·8	30·6	68·1	69·2
Loss on treatment ..	5·5	9·5	5·7	4·0	3·3	1·8
Carbon	3·15	3·55	1·30	0·83	0·93	0·65
Nitrogen	..	0·28	..	..	..	..
Gravel (field sample) ..	..	..	..	35·0	..	..
pH	5·5	5·4	5·5	5·9	5·7	5·6

TABLE XIX.—MECHANICAL ANALYSES OF NARRE CLAY LOAM.

Soil No.	C058.				C042.			
Horizon	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Depth (inches)	0–8	8–16	16–23	24–34	0–9	9–18	18–31	31–57
Coarse sand	24·9	32·4	26·7	29·3	20·6	25·2	23·5	24·3
Fine sand	22·0	21·3	21·6	21·1	23·9	23·1	23·1	22·1
Silt	19·3	16·7	17·2	15·5	17·8	17·2	15·9	15·6
Clay	27·1	25·6	32·5	32·0	30·0	31·9	35·1	36·7
Loss on treatment	4·7	3·2	2·3	1·9	5·5	2·6	1·4	1·0
Carbon	3·04	1·34	..	..	2·25	1·23	..	..
Nitrogen	0·19	..	..	..	..	..	..	..
Gravel (field sample)	..	..	..	..	..	..	..	..
pH	4·9	5·0	5·1	5·2	5·4	5·3	5·6	5·9

TABLE XX.—MECHANICAL ANALYSES OF TOOMUC SAND AND EUMEMMERING CLAY.

Soil No.	C059.			C043.			
Type	Toomuc Sand.			Eumemmering Clay.			
Horizon	*a*	*b*	*c*	*a*	*b*	*c*	*d*
Depth (inches)	0–14	14–32	32–37	0–6	6–16	16–33	33–42
Coarse sand	64·2	67·0	22·2	1·9	1·5	1·5	1·7
Fine sand	24·3	22·5	6·4	22·8	19·6	18·9	16·6
Silt	6·0	7·5	2·0	18·9	15·5	13·4	13·5
Clay	3·6	2·4	68·0	47·6	58·3	62·3	65·8
Loss on treatment	0·8	0·5	0·8	6·8	4·1	2·0	1·7
Carbon	0·84	0·17	..	3·46	2·05	1·06	1·47
Nitrogen	..	..	..	0·24	0·18	..	..
Gravel (field sample)	..	..	..	..	..	..	..
pH	4·1	5·5	5·0	5·5	5·8	6·6	6·7

TABLE XXI.—MECHANICAL ANALYSES OF RED AND BLACK SOILS ON BASALT.

Soil No.	C109.				C113.			
Phase	Red.				Black.			
Horizon	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Depth (inches)	0–9	9–17	17–27	27–39	0–5	5–10	10–27	27–32
Coarse sand	8·4	8·0	2·9	4·5	33·4	33·8	24·1	15·3
Fine sand	26·2	23·0	13·1	9·3	16·0	15·8	10·2	36·1
Silt	26·8	20·7	13·6	7·5	16·5	13·7	5·4	22·3
Clay	35·9	48·1	71·3	79·0	26·2	32·1	54·5	20·8
Loss on treatment	2·8	3·1	1·3	1·5	6·8	4·5	2·0	2·2
Carbon	3·91	1·72	1·31	0·66	4·22	..	..	..
Nitrogen	0·25	0·12	..	..	0·29	..	..	..
Gravel (field sample)	..	..	..	..	..	..	..	..
pH	5·8	6·3	6·1	6·1	5·4	5·5	6·5	7·0
Comments	..	..	..	..	..	..	..	Decomposing basalt

HYDROCHLORIC ACID EXTRACT.

Representative soils were extracted with boiling hydrochloric acid (as in the International method). Analyses of these extracts for potassium and phosphorus (expressed conventionally as K_2O and P_2O_5 respectively) are collected in Table XXII. Though the number of samples analysed from each type is small, some general relations may be pointed out from the figures.

Potassium.—The amount of potassium extracted from a soil by strong hydrochloric acid is generally related to the percentage of clay, and this is the case with these soils also. If we take 0.1 per cent. K_2O as the dividing line between fair and poor soils, the lighter types are low in potassium while the loams and clays (with one exception) have a good store. The high figure for the Silurian rock (C041e) is remarkable. This rock is well provided with potash-rich feldspars, and these constitute a valuable reserve against the impoverishment of the soil by leaching. The degree of availability of the HCl-soluble but non-exchangeable potassium of some of these soils is a matter of great interest. The sandier types (Harkaway, and especially Toomuc) are poor not only in immediately available potassium, but also in their reserves of the element.

The soils formed on the basalt are rather low in extractable potassium; however, the roots of plants growing on most of the soils can reach the layers of decomposing basalt, which contain primary minerals carrying rich reserves of potassium.

TABLE XXII.—POTASSIUM AND PHOSPHORUS DISSOLVED BY BOILING HYDROCHLORIC ACID.

—	—	Depth (inches).	K_2O	P_2O_5
Harkaway sand	C013*a*	0–10	·07	·019
	c	21–32	..	·010
Cranbourne sand	C057*a*	0–12	·012	·005
Toomuc sand	C059*a*	0–14	·015	·006
Toomuc sandy loam	C016*a*	0–8	·021	·016
	b	8–18	..	·004
	d	24–26	..	·006
	C006*a*	0–9	·06	..
	C092*a*	0–9	·05	·027
Hallam loam	C050*a*	0–8	·20	·028
	C0100*a*	0–7	..	·040
Hallam loam (silurian phase) ..	C041*a*	0–8	·24	·046
	b	8–12	·24	·015
	e	30–44	·47	·010
Narre clay loam	C058*a*	0–8	·05	·026
	C042*a*	0–9	..	·028
Eumemmering clay	C043*a*	0–6	·21	·059
	b	6–16	·22	·043
	C074*a*	0–10	·35	·113
Basaltic soils—				
Black	C102*a*	0–6	·09	..
	C103*a*	0–6	·11	..
	C113*a*	0–5	..	·038
Red	C104*a*	0–6	·07	..
	C106*a*	0–7	·21	..
	C108*a*	0–8	·06	·140
	b	8–20	·03	·130
	C109*a*	0–9	..	·053
	c	17–27	..	·041

Phosphorus.—Most of the soils analysed illustrate the general poverty of Victorian soils in phosphorus. Of the non-basaltic types, only Eumemmering clay reaches as high as 0.05 per cent. P_2O_5, and one sample of this type exceeds 0.1 per cent. The lighter types are poor or very poor, and even the two best samples of Hallam loam have been given unusual amounts of additional phosphate. The phosphorus content of the Silurian rock stands in marked contrast to the figure for potassium. The basaltic types are interesting. The deep, mature soils (C109, C113) have lost most of their original supply, but the immature sample (C108), which contains still decomposing basalt, is fairly rich in phosphorus. Figures of the order of 0.1 per cent. P_2O_5 have been obtained for several other soils on the basalt in this area, and these soils appear to be generally richer than the non-basaltic types.

Organic Matter.

Organic carbon (Table XXIII) was estimated by Tiurin's rapid approximate method (using the figure 1 ml. normal oxidizing agent equals 3.3 mg. carbon); the total organic matter may be calculated by multiplying these figures by 1.73. The figures range from low values for the sandiest types to high values for the basaltic types and Eumemmering clay. The total organic matter in some basaltic soils exceeds 10 per cent.—a figure which is evidently due to the high chemical fertility of these soils as well as to their moisture-retaining capacity; both of these factors

Table XXIII.—Distribution of Carbon Content of Surface Soils (by Tiurin's Method).

Soil Type.	Carbon, Percentage.										
	Mean.	0·5–1·0.	1·0–1·5.	1·5–2·0.	2·0–2·5.	2·5–3·0.	3·0–3·5.	3·5–4·0.	4·0–5·0.	5·0–6·0.	6·0–7·0.
Harkaway sand	1·6	..	2	..	1	..	..	..	..	..	..
Cranbourne sand	1·1	1	1	..	..	..	..	..	..	..	..
Toomuc sand	0·8	1	..	..	..	..	..	..	..	..	..
Toomuc sandy loam	2·2	..	1	..	..	1	1	..	..	..	..
Hallam loam	3·4	..	..	..	..	..	2	2	..	..	..
Narre clay loam	2·7	..	..	..	1	..	1	..	..	..	..
Eumemmering clay	4·4	..	..	..	..	..	1	..	..	1	..
Red-brown basaltic clay loam ..	5·3	..	..	..	..	..	..	1	1	2	1
Black basaltic clay loam ..	4·5	..	..	..	..	1	..	..	2	..	1

increase the annual addition of plant residues to the soil, and hence lead to a high content of humus. The relatively high figures for the samples of Hallam loam are interesting, and would hardly be expected from their pale appearance.

These samples, as might be expected, are also rather high in organic nitrogen, but the improvement in fertility caused by the growth of subterranean clover indicates that the quality of this nitrogen for plant growth is not high.

Salt Content of Soils.

Normal Soils.—The soils of the area are generally low in soluble salts, as might be expected from the nature of the climate. Several representative samples were analysed both for total salt (conductometrically) and for chloride.

The majority of surface soils contain less than 0.01 per cent. of sodium chloride. A few figures are collected in Table XXIV which shows that salt reaches moderate amounts only in a few deep subsoils.

Saline Patches.—The surface 6 inches of the bare saline patches contain as much as 0.8 per cent. of sodium chloride, with an average of 0.44 per cent. for nine samples. The lower layers are also saline, but the highest concentrations are invariably found on the surface; this indicates that water is held up by the clay subsoil in the second foot long enough for capillary rise and evaporation at the surface to be an important factor. The two series of samples quoted in Table XXV (C047 to C045, C050 and C051) are very interesting in showing how localized the salt is; a chain away from the edge of a bare patch the salinity is down to normal levels.

Analyses of the extracted salt show that sodium and chloride are the predominant ions, and magnesium and sulphate occur in appreciable amounts. The salt, in fact, approximates in composition to sea-salt.

Table XXIV.—Chloride in Normal Soils, Reckoned as Sodium Chloride.

Soil Type.	Sample Number.	Depth. (inches)	NaCl, parts per 100,000.
Toomuc sandy loam	C016*e*	26–46	10
	C092*c*	16–26	20
	C092*g*	64–72	100
Hallam loam	C038*a*	0–6	10
	C038*d*	16–21	10
Eumemmering clay	C043*a*	0–6	0
	C043*b*	6–16	20
	C043*c*	16–33	100
	C043*d*	33–42	170
	C061*a*	0–6	10
	C061*d*	25–32	80
	C074*c*	20–36	10

All the above samples have a clay texture except CO38*a*. Many figures for lighter soils have been omitted, all being low.

TABLE XXV.—CHLORIDE IN SALINE SOILS, RECKONED AS SODIUM CHLORIDE.

Soil Type.	Sample Number.	Depth. (inches)	Plant cover.	NaCl, parts per 100,000.
Toomuc sandy loam .. .. (Series within one chain)	C047*a*	0–8	Normal pasture	20
	C046*a*	0–6	Plantago	80
	C045*a*	0–8	Bare	260
	c	12–15	..	70
	e (clay)	28–36	..	60
Hallam loam .. .. (Series within one chain)	C050*a*	0–8	Normal pasture	10
	C051*a*	0–6	Bare	760
Toomuc sandy loam	C044*a*	0–7	Bare	530
	b	7–12	..	260
	c	12–18	..	160
	C065*a*	0–6	Bare	430
	b	6–15	..	100
	c	15–17	..	50

pH VALUES.

Reactions were determined by means of the quinhydrone electrode, using equal weights of soil and water. The distribution of the pH values of the surface, subsurface, and subsoil is shown in Table XXVI. Considering surface soils first, it will

TABLE XXVI.—DISTRIBUTION TABLE OF pH VALUES (QUINHYDRONE ELECTRODE).

—	Mean.	3·0–3·5	3·5–4·0	4·0–4·5	4·5–5·0	5·0–5·5	5·5–6·0	6·0–6·5	6·5–7·0	7·0–7·5
Harkaway sand—										
Surface	5·7	..	..	..	..	1	3	..	..	..
Subsurface	5·6	..	..	..	..	1	1	..	..	..
Subsoil	6·0	..	..	..	..	..	2	..	1	..
Cranbourne sand—										
Surface	4·4	1	..	..	1	1	..	..	..	..
Subsurface	4·3	1	..	..	2	..	..	..	..	..
Subsoil	4·5	..	1	..	1	1	..	..	..	..
Toomuc sand—										
Surface	4·1	..	..	1	..	..	..	..	..	..
Subsurface	5·1	..	..	..	..	1	..	..	..	..
Subsoil	5·3	..	..	..	..	1	..	..	..	..
Toomuc sandy loam—										
Surface	5·4	..	..	..	..	4	5	..	..	..
Subsurface	5·5	..	..	..	..	2	2	..	..	..
Subsoil	5·9	..	..	..	..	1	2	..	1	..
Hallam loam—										
Surface	5·4	..	..	..	3	3	4	1	..	..
Subsurface	5·4	..	..	..	1	2	1	1	..	..
Subsoil	5·3	..	..	..	1	..	2	..	..	..
Saline soils— (These all belong to above two types)										
Surface	4·8	..	..	2	4	..	..	..	1	..
Subsurface	5·5	..	..	..	2	..	2	..	1	..
Subsoil	5·6	..	..	..	..	2	1	..	..	..
Narre clay loam—										
Surface	5·1	..	..	..	2	2	..	..	..	..
Subsurface	5·3	..	..	..	..	3	..	..	..	..
Subsoil	5·4	..	..	..	..	2	1	..	..	..
Eumemmering clay—										
Surface	5·3	..	..	..	..	3	1	..	..	..
Subsurface	5·9	..	..	..	..	..	1	1	..	..
Subsoil	5·8	..	..	..	1	..	1	..	1	..
Red-brown basaltic clay loam—										
Surface	5·6	..	..	..	..	2	5	..	..	..
Subsurface	5·7	..	..	..	..	1	4	1	..	..
Subsoil	6·1	..	..	..	..	..	1	1	1	..
Black basaltic clay loam—										
Surface	5·5	..	..	..	..	1	2	..	..	..
Subsurface	6·2	..	..	..	..	..	1	2	..	..
Subsoil	6·6	..	..	..	..	..	..	2	1	1

be seen that acidic reactions are the rule throughout, only one normal surface soil reaching even to pH 6; and this is so in spite of the light dressings of lime which have been applied to some properties. The majority of the samples of the commonest types lie between 5 and 6, with a large number of readings more acid than 5.5. The lightest type—Cranbourne sand—is the most acidic of all throughout the profile, and is the only type on which acidity appears to limit the growth of plants—though, of course, only plants which are fairly tolerant of acidity are widely grown in this district in any case.

There is a tendency towards a higher pH value in the lower layers of some soil types, a tendency which is most marked in the black basaltic type.

The saline soils have been grouped separately; they are definitely more acidic than the normal soils of the same type, with the exception of one which is more alkaline than the normal soils. It is possible that these soils owe their acidity to recent accession of salt, in conformity with the general rule that the pH of a soil suspended in a salt solution is lower than in pure water; while the more alkaline sample may represent a more mature phase of the interaction of soil with a sodium salt.

Exchangeable Cations.

The four main elements extracted by leaching with normal ammonium acetate at pH 7 are recorded in Table XXVII. Those

Table XXVII.—Exchangeable Cations.

Soil Type.	Sample No.	Depth. (in.)	Exchangeable Cations. Percentage of Total.				Exchangeable Cations. Total in milliequiv. per 100 gm. Oven-dry Soil.	pH.	Percentage Clay.
			Ca.	Mg.	Na.	K.			
Harkaway sand	C013*a*	0–10	65	28	2	5	4·3	5·9	7·5
Toomuc sandy loam—									
Normal Phase	C016*a*	0–8	52	37	8	3	1·9	5·6	5·5
	C016*b*	8–18	58	32	7	3	0·9	5·4	6·1
	C016*e*	26–46	7	81	11	1	10·2	5·4	47·8
	C092*a*	0–9	55	38	5	2	4·2	5·1	10·2
	C092*e*	16–26	18	66	15	1	12·9	5·6	41·9
Saline phase	C045*a*	0–8	18	54	25	3	2·1	4·5	..
	C045*e*	28–40	10	64	25	1	6·1	5·4	..
Hallam loam—									
Normal phase	C0100*a*	0–7	58	37	3	2	9·2	5·3	17·9
	C0100*d*	15–20	19	71	9	1	15·7	5·3	55·1
Heavy phase	C038*a*	0–6	45	50	3	2	12·1	5·4	27·2
	C038*d*	16–21	23	70	6	1	18·8	5·7	68·1
Silurian phase	C041*a*	0–8	55	38	5	2	7·3	4·7	21·0
Narre clay loam	C058*a*	0–8	36	58	5	1	15·2	4·9	27·1
Eumemmering clay	C043*a*	0–6	42	52	4	2	23·7	5·5	47·6
	C043*b*	6–16	33	58	7	2	26·1	5·8	58·3
	C043*d*	33–42	25	59	14	2	30·1	6·7	65·8
	C074*a*	0–10	37	57	4	2	19·6	5·1	..
	C074*e*	20–36	26	67	5	2	21·9	4·9	..
Red-brown basaltic clay loam	C109*a*	0–9	53	39	3	5	13·4	5·8	35·9
	C109*c*	17–27	31	63	5	1	11·2	6·1	71·3
	C109*d*	27–39	26	66	6	2	10·5	6·1	79·0
Black basaltic clay loam ..	C113*a*	0–5	54	42	3	1	19·1	5·4	26·2

surface soils which are relatively low in clay are poorly supplied with these four elements; but even the heavier soils have not a very good supply, partly because of their acidity—in other words, because acidic hydrogen takes up a large proportion of the soil's capacity for holding cations. Most of the subsoils (which are high in clay) contain more of the exchangeable elements than the surface soils, though the red basaltic type C109c and d) is remarkably low in this respect. Such a low capacity for holding cations is a feature of highly ferruginous soils in other parts of the world.

The available *calcium* in the soil may be taken as equivalent to the exchangeable calcium. Among the podzolic types of soil (Harkaway, Toomuc, Hallam) this is always less than 0.15 per cent. of "lime" (CaO). If we accept G. W. Robinson's opinion (9) that lime is needed on all soils with less than 0.25 per cent. of exchangeable calcium reckoned as CaO (or 9 milli-equivalents per cent.) then all these types are deficient except the Eumemmering clay and the black basaltic type.

The figure for exchangeable *potassium* gives useful information as to the amount of available potassium. Here again the podzolic types are poorly equipped. Harkaway sand, containing reserves of primary minerals which keep up the supply, is probably safe against potassium deficiency, but the Hallam and Toomuc types are poor. Sample C016 was taken from a property which was heavily cropped with oats in former years, and on which there is reason to believe that the present pasture is deficient in potassium. The exchangeable potassium in the surface 8 inches corresponds to only 50 lb. of the element per acre.

Relative Importance of the Four Elements.—The surface soils contain calcium and magnesium in roughly equivalent amounts. The subsoils, however, contain magnesium in predominant amounts, even up to 80 per cent. of the total exchange capacity of the soil, while calcium drops to one-third, or even less, of the magnesium. Sodium also increases in the subsoil and reaches the same order as calcium in two normal samples. In a very poor saline soil sodium reaches 25 per cent. of the total, and calcium falls to third place.

This occurrence of magnesium- or magnesium-sodium-clays is common in Victoria, and appears to be related to the incidence of cyclic salt already referred to (p. 195). The uptake of calcium and magnesium by the native trees and grasses which formerly covered the country might also have an interesting connexion with these figures for exchangeable ions.

Composition of Clay Fractions.

The material of less than 0.001 mm. diameter was isolated from selected soils and the results of a complete analysis are collected in Table XXVIII. Among the podzolic types the clays of the grey surface soils are highly siliceous, while those of the yellowish subsoils are relatively higher in aluminium and iron. The red basaltic soil is much less siliceous, both in the surface and in the subsoil. The high concentration of iron in the surface clay of this type is interesting. The high content of titanium in the surface clays of both types is striking; the parent rocks are also high in titanium.

Table XXVIII.—Chemical Composition of Clay Fractions Below 0.001 mm. Diameter.

Soil Types.	Depth. (in.)	Percentage Composition.				Molecular Ratios.	
		SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	$\frac{SiO_2}{Al_2O_3}$.	$\frac{SiO_2}{Al_2O_3 + Fe_2O_3}$.
Hallam loam, grey surface—							
C038*b* ..	6–11	43·4	19·9	9·4	7·8	3·65	2·81
C099*a*, *b* (Composite)	0–13	48·8	24·6	5·2	5·0	3·28	2·90
Hallam loam, yellow subsoil—							
C038*e* ..	21–32	41·3	25·2	10·9	2·5	2·73	2·14
C092*e* ..	16–26	42·5	27·0	9·5	1·6	2·63	2·15
Red basaltic—							
C109*a* ..	0–9	35·3	24·3	16·4	5·4	2·44	1·70
C109*d* (Composite)	27–39	37·7	32·5	9·3	1·0	1·95	1·67

Mineralogy of "Fine Sand" Fractions.

The "fine sand" fractions (i.e., particles of diameter between 0.2 and 0.02 mm.) were isolated from selected samples, and the following information has been supplied by Miss A. Nicholls, M.Sc., who kindly examined them for their minerals.

Harkaway sand (on granodiorite).—Quartz predominant. Plagioclase and orthoclase common as large and fresh fragments. Hornblende rare. Mr. G. Baker has kindly provided the following information from a Rosiwal analysis of the granodiorite itself:—Quartz, 24 per cent.; orthoclase, 17 per cent.; plagioclase, 39 per cent.; biotite, 15 per cent.; hornblende, 5 per cent. Apatite also is present.

Cranbourne sand.—Almost pure quartz, feldspars absent.

Toomuc sandy loam.—Quartz predominant, a few grains of decomposed plagioclase and orthoclase

Hallam loam and Eumemmering clay.—Similar to Toomuc sandy loam.

These four soils, derived from unconsolidated sediments, contain only poor reserves of primary minerals.

Hallam loam (Silurian phase).—Richer in orthoclase and plagioclase than the four types just mentioned; especially as the parent rock is approached. Hornblende, apparently wind-blown, occurs in surface of both samples, in appreciable amounts.

Black basaltic soil (C113b).—This is a "mature" soil; most of the original minerals of the basalt have been decomposed and the fine sand contains mainly quartz. Plagioclase is less important than in the last-mentioned soil. Magnetite is common. A few grains of augite are present, probably due to the survival of a few "floaters" of rock through the profile.

The red and black soils formed on basalt through Gippsland are usually similarly devoid of the rich primary minerals which the original basalt contained.

VII. Botanical Surveys.

Several different associations of plants occur on the various types of land in this district. We are greatly indebted to Miss Y. Aitken, M.Agr.Sc., for carrying out a botanical survey of some of these associations, the results of which are given below:—

WOODED SLOPES OF HILL COUNTRY NORTH OF BEACONSFIELD. SOIL TYPES, HARKAWAY SAND ON GRANODIORITE AND RUGGED SILURIAN COUNTRY.

The bush in this area is an association of trees, mainly Messmate (*Eucalyptus obliqua*), Peppermint (*E. australiana*), and Blackwood (*Acacia melanoxylon*), with scattered woody shrubs and tussock grasses. The trees are about 5 yards apart in the upper sections of the slopes, but they and the other growth become more dense lower down (cf., pl. XII, fig. 2), and begin to include more hydrophilic species such as *Melaleuca squarrosa* (Swamp Paperbark), rushes, &c. The amount of bare space in a square-foot quadrat is about 80 per cent. on the upper slopes, and about 70 per cent. on the lower slopes. The ground is covered mostly by dead leaves of Peppermint and Messmate. No distinct difference is evident between the flora from each type of soil on similar slopes. However, of the two species of tussock grasses, *Poa caespitosa* and *Danthonia pallida*, the former tends to be characteristic of the granodiorite and the latter of the Silurian country. The bush described here is typical of large areas, but its composition may well have been affected by the frequent fires since white settlers arrived.

Sandhills near Cranbourne. (Soil type, Cranbourne Sand).

(*a*) *Virgin Scrub.*—The original vegetation of the deep sand, here named Cranbourne sand, is a xerophytic scrub association, of woody shrubs and some scattered trees. Typical quadrats show that about 50 per cent. of the ground is bare. The commonest tree is Peppermint (*E. australiana*), and Manna gum (*E. viminalis*) occurs occasionally as a stunted form.

The shrubs are much less varied than in the hilly country just described, and range up to 6 feet high. They are chiefly Silky Teatree (*Leptospermum myrsinoides*), with Wedding bush (*Ricinocarpus pinifolius*), Bundled Guinea flower (*Hibbertia fasciculata*), a species of Bush pea (*Pultenea* sp.), and Broom Spurge (*Ampera spartioides*) frequent.

In places where the scrub has been partly cleared, Bracken (*Pteridium aquilinum*) and Wild Parsnip (*Didiscus pilosa*) have formed closed communities.

(*b*) *Cleared land.*—Part of this area has been cleared, and is now an open association of Bracken, Sorrel (*Rumex acetosella*) and Yorkshire Fog (*Holcus lanatus*) with some Barley Grass (*Hordeum murinum*) and Silver Grass (*Festuca bromoides*), and Bent Grass (*Agrostis* sp.). In a depression, the greater moisture has made possible a complete cover of annual clovers (*T. recumbens, T minus*), White clover (*T. repens*), and Yorkshire Fog.

Tea-tree Swampland. (Soil type, Narre clay loam.)

The slope described in the last paragraph descends to a tongue of tea-tree swamp. This land is covered by Swamp Paperbark (*Melaleuca ericifolia*) about 8 feet in height. This scrub is so dense that very few other plants survive. Tall sedge (*Carex appressa*) occurs near the edge of the scrub.

Where the scrub has been cleared the land carries a moderately open association of grasses, mainly native, and some herbs. Small tussocks of *Poa caespitosa* are the most prominent feature.

Unimproved Native Pasture. (Soil types, Hallam loam, Toomuc sandy loam.)

The gently sloping land to the south of the Highway was formerly covered with species of Eucalyptus. Where the timber has been removed but the pasture has not been improved, this land carries to-day a characteristic association of native grasses. Such an association is found for example on the drier ground on the edge of the swamp just described. This is characterized by:—Kangaroo grass (*Themeda triandra*), various Wallaby grasses (*Danthonia semi-annularis, D. pilosa, D. penicillata*), and introduced plants, mainly Yorkshire Fog, Sweet Vernal grass (*Anthoxanthum odoratum*), Flatweed or Cat's ear (*Hypochaeris* *radicata*) and *Plantago coronopus.* Kangaroo and Wallaby grasses are typical of this better drained land, while *Poa caespitosa* is dominant on the swampy flats

Special Areas.

(*a*) *Very Acid Areas.*—In a cleared field of Cranbourne sand the normal pH ranges from 4 to 5, and the plant association consists of Bracken, Sorrel, Yorkshire Fog, Subterranean Clover, and Hair and Silver grass. Some highly acid patches occur, however, with a pH value close to 3.5; one sample even recorded pH 3.1. These patches carry a Sorrel association which is pure apart from several plants of Hair grass (*Aira praecox*). Even these tolerant plants, however, form such a sparse association that 90 per cent. of the ground is bare.

(*b*) *Saline Areas.*—A number of saline patches occur at the foot of slopes. The land here consists of quite bare areas alternating with pure stands of Buck's horn Plantain (*Plantago coronopus*). Towards the edge of such patches, Cat's ear, Couch (*Cynodon dactylon*), love grass (*Eragrostis diandra*), Sweet Vernal grass, and Wallaby grass occur in turn. The Plantain is very dwarfed compared with its growth in normal pastures, and occurs in a density of about 40 plants per 6-inch square. The high tolerance of this plant towards salt is well known.

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Explanation of Plates.

Plate IX.

Types of country in the Berwick district. (Photographs by B. A. Pearl.) Upper left—General view of plains from a basaltic hill. Upper right—Apple orchard on lower slopes in rugged Silurian hills. Lower left—Tongue of Narre clay loam carrying tea-tree. Lower right—Cleared basaltic hills in background, uncleared Silurian hills to right (looking north from Berwick).

Plate X.

Fig. 1.—Hallam loam on Silurian mudstone. The wooden handle is 14 inches long.

Fig. 2.—Harkaway sand, showing the very light sub-surface layer, resting on sandy clay.

Fig. 3.—Gully eroded, following the scooping out of a drain.

Plate XI.

Fig. 1.—House on Hallam Valley settlement.

Fig. 2.—Salt patch at foot of slope. The native grasses give way to Plantago.

Fig. 3.—Head of gully shown on preceding plate.

Fig. 4.—Salt patch at foot of a Silurian ridge. The bare ground has been badly eroded.

Plate XII.—Aerial Photographs.

Fig. 1.—Bare patches, affected by salt, at the foot of parallel ridges of Silurian rock. The land between these patches is flat and poorly drained.

Fig. 2.—Orchard in rugged Silurian hills. The lighter patches in the timbered country are the ridges, the darker patches are the valleys which are more densely covered. The effect of erosion in the orchard is shown by the healthier trees in the basin.

Fig. 3.—Highly improved pasture (white clover and perennial rye grass) in the upper centre, native pasture on the other side of the fence. The light patch in the improved property is being cultivated in preparation for a summer crop.

Fig. 4.—The dense vegetation is silver tea-tree growing on Narre clay loam in a depression along a watercourse. The open timber just to the west is "peppermint" growing on the Silurian phase of Hallam loam on rising land.

Fig. 5.—A similar transition to that in fig. 4 showing on cultivated soil after rain. The dark soil is Eumemmering clay, the light soil is the Silurian phase of Hallam loam. There are some bad saline patches on the latter type, which have been eroded to a depth of 9 inches (plate XII, fig. 4).